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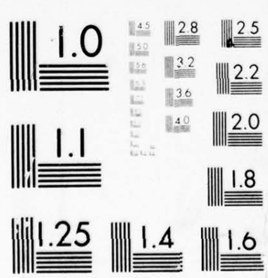

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NWHC REPORT 7732
16 MAY 1977

NAVAL WEAPONS HANDLING CENTER

TECHNICAL REPORT

DYNAMIC ANALYSIS OF SHIPPING CONTAINER SUSPENSION SYSTEM FOR THE ASROC LAUNCHED VERSION OF THE HARPOON MISSILE RGM-84A-1

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DEPARTMENT OF THE NAVY
SEA SYSTEMS COMMAND

NAVAL WEAPONS STATION EARLE
COLTS NECK, N.J.

NAVAL WEAPONS STATION EARLE
Colts Neck, New Jersey 07722

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An analysis was conducted by Naval Weapons Handling Center, WPNSTA Earle to determine isolation system parameters for a shipping and storage container to be used with the ASROC launched version of the HARPOON missile. A computer program package specifically written for container designers was used and is the main computational tool in the analysis. Two possible solutions to the isolation systems are presented. The primary difference between the solutions is that unlike Solution 1, Solution 2 uses offset isolators, thereby resulting in better placed longitudinal and vertical frequencies and lower sway space over

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20. ABSTRACT (cont'd)

requirements. This report presents the details of the analysis and provides information concerning the predicted shock and vibration forces on the weapon caused by the hazards of transportation and handling.

ABSTRACT

An analysis was conducted by the Naval Weapons Handling Center, WPNSTA Earle to determine isolation system parameters for a shipping and storage container to be used with the ASROC launched version of the HARPOON missile. A computer program package specifically written for container designers was used and is the main computational tool in the analysis. Two possible solutions to the isolation system are presented. The primary difference between the solutions is that unlike Solution 1, Solution 2 uses offset isolators, thereby resulting in better placed longitudinal and vertical frequencies and lower sway space requirements. This report presents the details of the analysis and provides information concerning the predicted shock and vibration forces on the weapon caused by the hazards of transportation and handling.

Prepared by: G. Johnson
G. JOHNSON
Mathematician

Reviewed by: E. Rinaldi
E. RINALDI
Analysis Branch

Approved by: R. E. Seely
R. E. SEELY
Test & Evaluation Division

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INTRODUCTION

The Naval Weapons Handling Center, WPNSTA Earle was tasked the development of a shipping and storage container for the ASROC launched version of HARPOON. The basic technical tasks in the development consist of the isolation system design, the container structural design and experimental verification of the design by test and evaluation of the prototype container.

The subject of this report is the isolation system design. The outputs of the report are design parameters used by both shock mount manufacturers and container structure designers. From their individual efforts a prototype container is designed, fabricated, and subsequently tested. The design parameters of interest to the mount manufacturers consist of the required natural frequency and damping characteristics of the isolation system. The location of the shock mounts and the reaction loads developed by the isolation system's response to the shock and vibration environment are inputs to the structural designers. Thus, all information necessary to develop a container design with respect to shock and vibration isolation is provided.

The design specification that these parameters address are contained primarily in two specifications, XAS 2381 (HARPOON Missile Environmental Design Criteria Specification) and XAS 3894 (Container Specification).

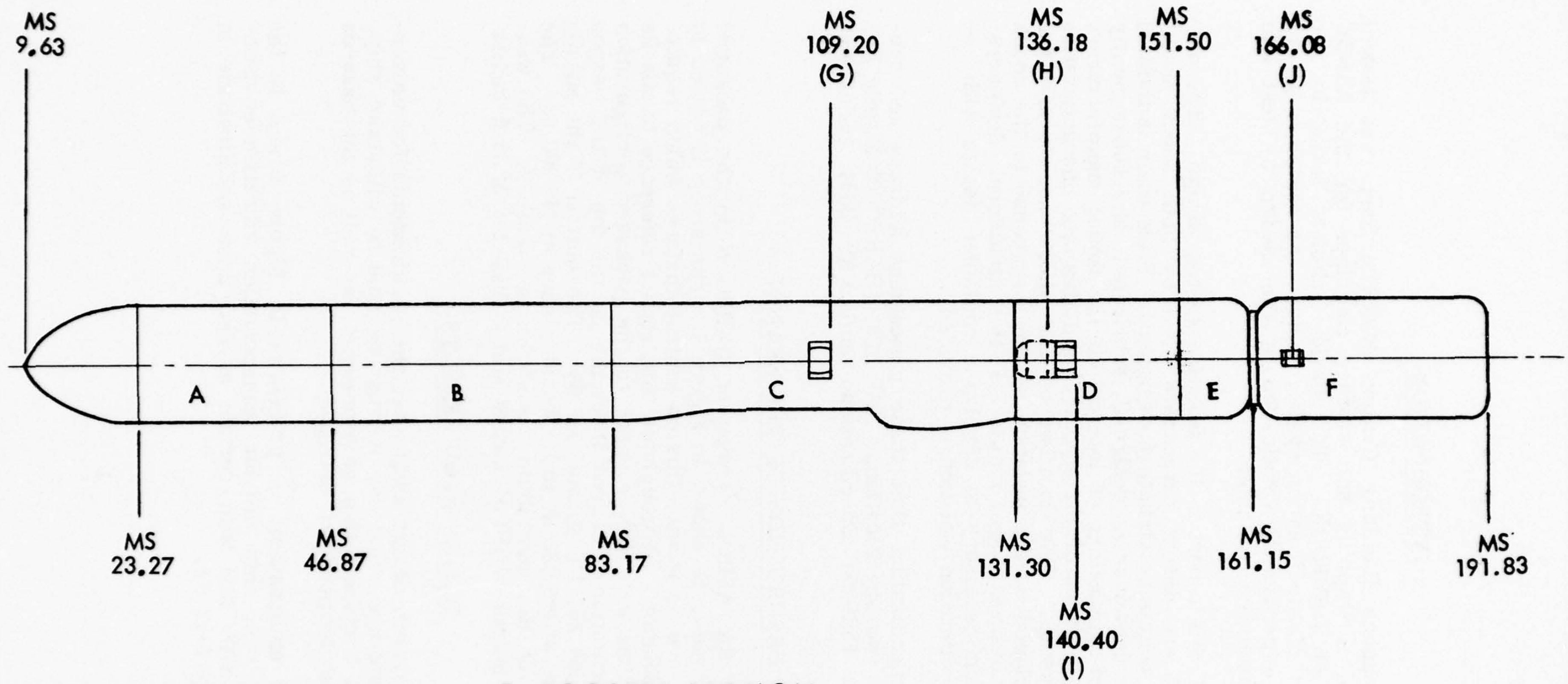
DESCRIPTION OF THE WEAPON

A diagram of the ASROC version of HARPOON in the packaged configuration (plan view) is shown in Figure 1. The scoop is placed to the side and there are no wings, fins or control surfaces which require consideration for isolation. Throughout this report reference to missile sides, top and bottom are with respect to the packaged configuration (90° from flight orientation). Three shoes are on the top of the weapon at missile stations 109.20, 140.40 and 166.08. The bottom of the missile has a restraint shoe at MS 136.18 and a booster shoe at MS 166.08. The missile weighs 1365.08 lbs. distributed as shown in Figure 2. The weapon has an overall length of 180.37 inches and a diameter of 13.5 inches.

DESIGN REQUIREMENTS

The isolation system design must meet the requirements for universal shipping and storage, that is, it must be able to withstand ship, air, rail and truck transportation environments, as well as the hazards of rough handling at temperature extremes.

The vibration environment is presented in Figure 3 and is the envelope of truck, rail, ship and air transportation vibration environments taken from XAS 2381 with certain agreed upon modifications in the frequency range 5-12 Hz.

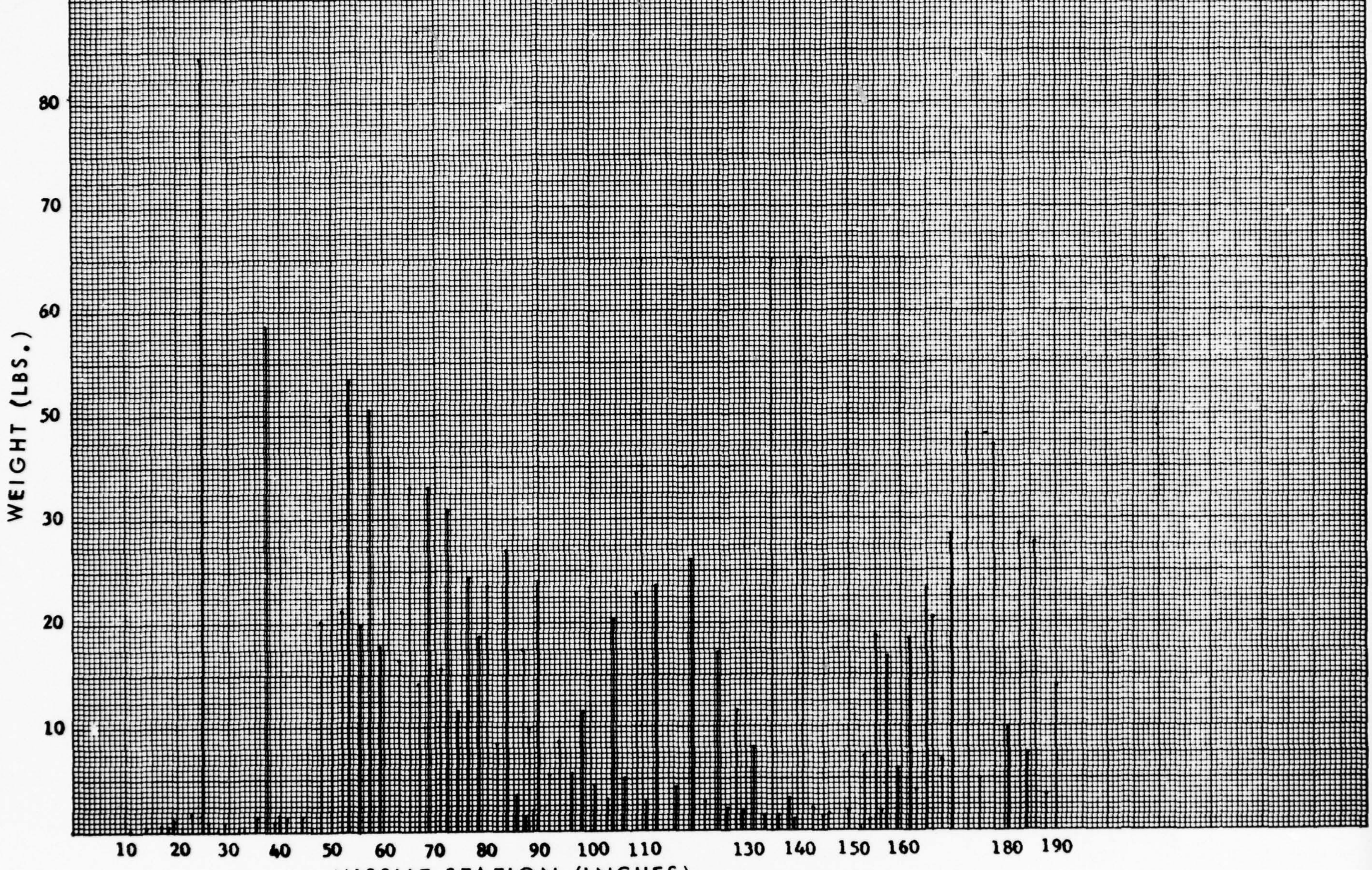


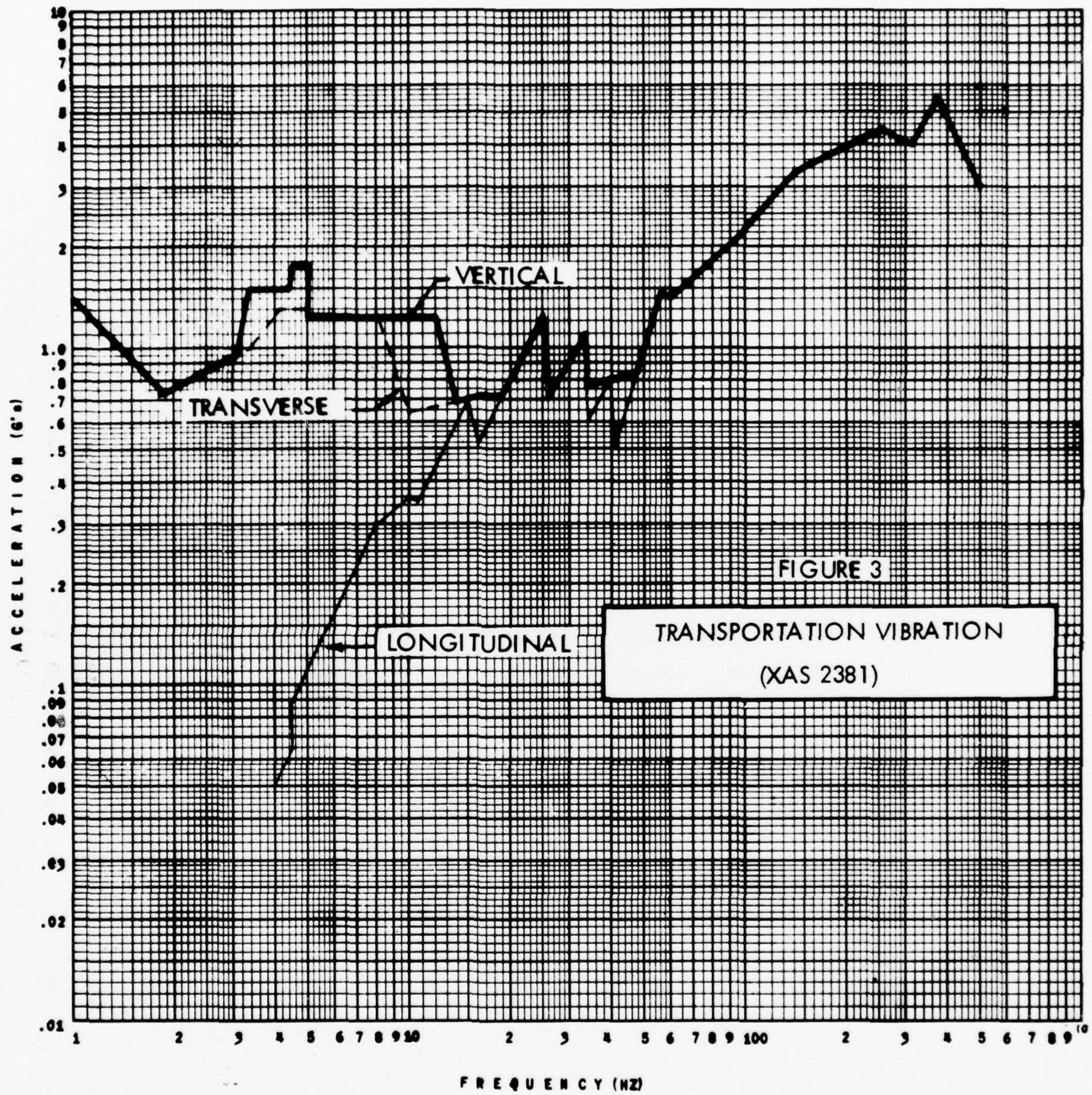
A GUIDANCE SECTION
B ORDNANCE SECTION
C TANK SECTION
D ENGINE SECTION
E BOAT TAIL SECTION

F BOOSTER SECTION
G FORWARD SHOE
H RESTRAINT SHOE
I AFT SHOE
J BOOSTER SHOE (BOTH SIDES)

FIGURE 1. HARPOON MISSILE, ASROC VERSION (PLAN VIEW)

FIGURE 2. HARPOON MISSILE, ASROC VERSION
WEIGHT DISTRIBUTION




VERTICAL
TRANSVERSE
LONGITUDINAL
FIGURE 3
TRANSPORTATION VIBRATION
(XAS 2381)
ACCELERATION (G's)
FREQUENCY (HZ)

The vibration fragility design levels for the ASROC version of HARPOON as shown in Figure 4. In particular the major factor influencing these levels is the sensitivity of the sustainer engine. The design temperature for vibration is specified to be standard room temperature. This is common practice and reflects the fact that cold mounts tend to warm up when they are exercised because of heat generated by energy dissipation because of damping, and that elevated transportation temperatures, which are less than storage temperatures, are not sufficient to significantly affect mount properties.

In the logistics cycle for the ASROC version of HARPOON, shock incidents may occur as a result of hazards due to storage and associated handling, transfer at sea, and railcar coupling. In addition to handling induced shocks, shock resulting from the near-miss environment has been considered.

The shock environment is specified primarily in terms of shock tests as listed in Table 1. The weapon in its container is expected to survive the tabulated tests at temperature extremes of -20°F and 140°F, with the exception of the near-miss eligibility test which is conducted at 70°F.

Shock survival criteria (design levels) used in the analysis address the acceleration design levels for HARPOON components, bending and axial load limits for the missile structure, and interface reaction limits between the missile and container. The acceleration design level for the HARPOON components is specified as a 42 g terminal peak sawtooth with a duration of not less than 25 ms. The allowable bending and axial loads are combined as allowable equivalent axial loads presented in Figures 5 and 6. The vertical interface locations were required by XAS 3894 to be at MS 66.7 and 170 which are designated hard areas whose load carrying capability is well beyond the maximum possible reaction forces which may occur as a result of the specified shocks. The ASROC restraint shoe at MS 136 is designated to be used for longitudinal restraint of the weapon. Its load carrying capacity is specified as 16,240 lbs. In addition, friction type longitudinal restraints are permitted at MS 66.7 and 170.

DESIGN APPROACH

Traditionally, establishing the isolation system parameters of natural frequency and damping has been accomplished without a detailed consideration of the packaged item's vibration fragility or environmental excitation. Damping was specified in terms of maximum transmissibility which was, in turn, derived from a recognition of the damping properties of state of the art isolation system materials. Isolation system natural frequency was required to be within the range where occurrences of transportation excitation were not common. Design to specific weapon fragilities and transportation environments was avoided because of their general incompatibility. Vibration fragility levels were predicted solely on operational considerations which did not recognize the

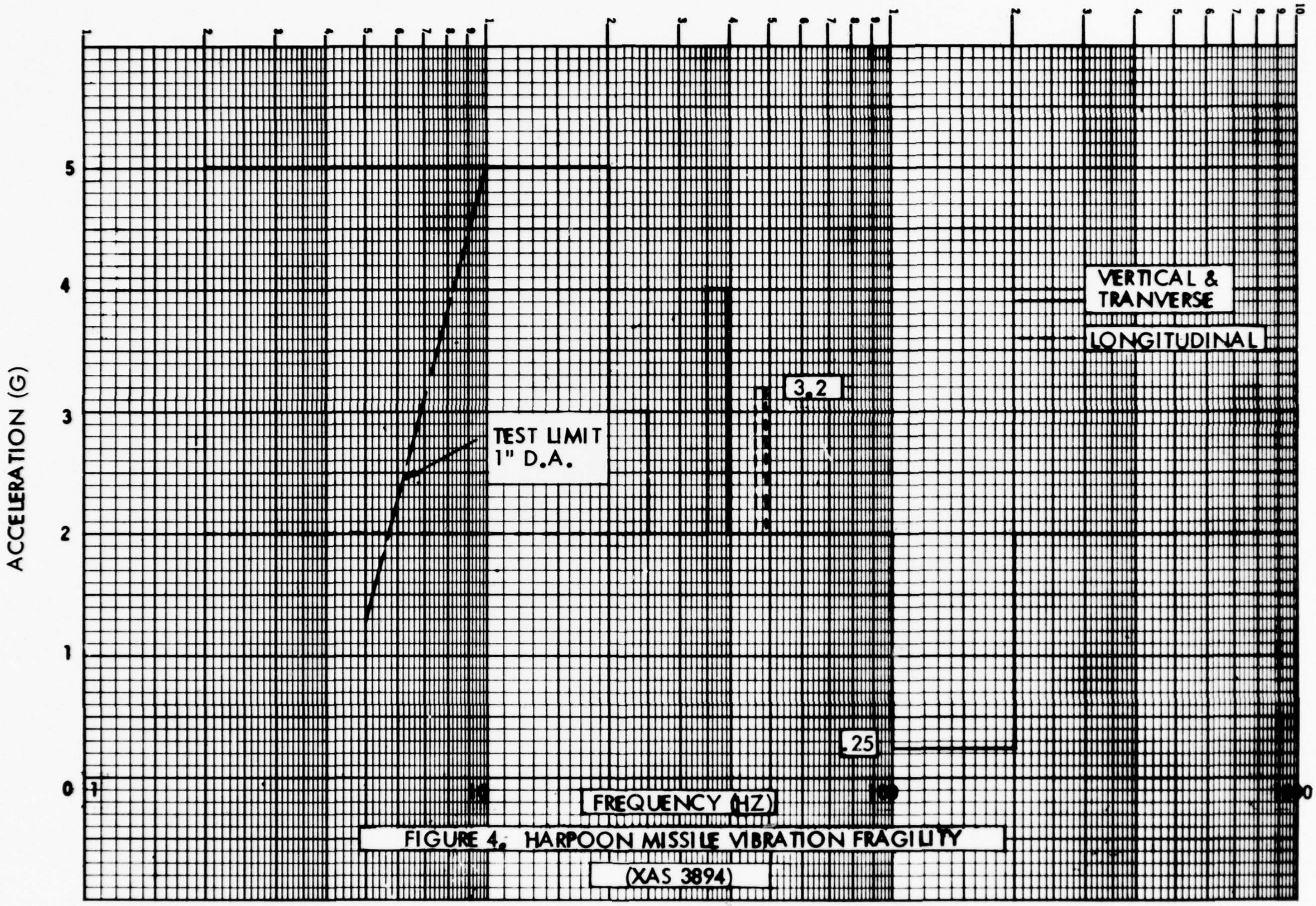


FIGURE 4. HARPOON MISSILE VIBRATION FRAGILITY

(XAS 3894)

TABLE 1

SHOCK ENVIRONMENTS

SHOCK EVENT	SPECIFICATION	APPLICABLE TEMPERATURES
Storage and Handling	18 inch rotation corner drop	-20°F - 140°F
Railcar Coupling	10 ft/sec end impact 25g, 25ms, half sine	-20°F - 140°F
Transfer at Sea	10 ft/sec end impact	-20°F - 140°F
Near-Miss Eligibility	18 inch flat drop	70°F
Ship Shock	15g, 35ms trapezoid-10ms rise and decay-vertical	70°F
	9g, 35ms trapezoid-10ms rise and decay-lateral	70°F
	6g, 35ms trapezoid-10ms rise and decay-longitudinal	70°F

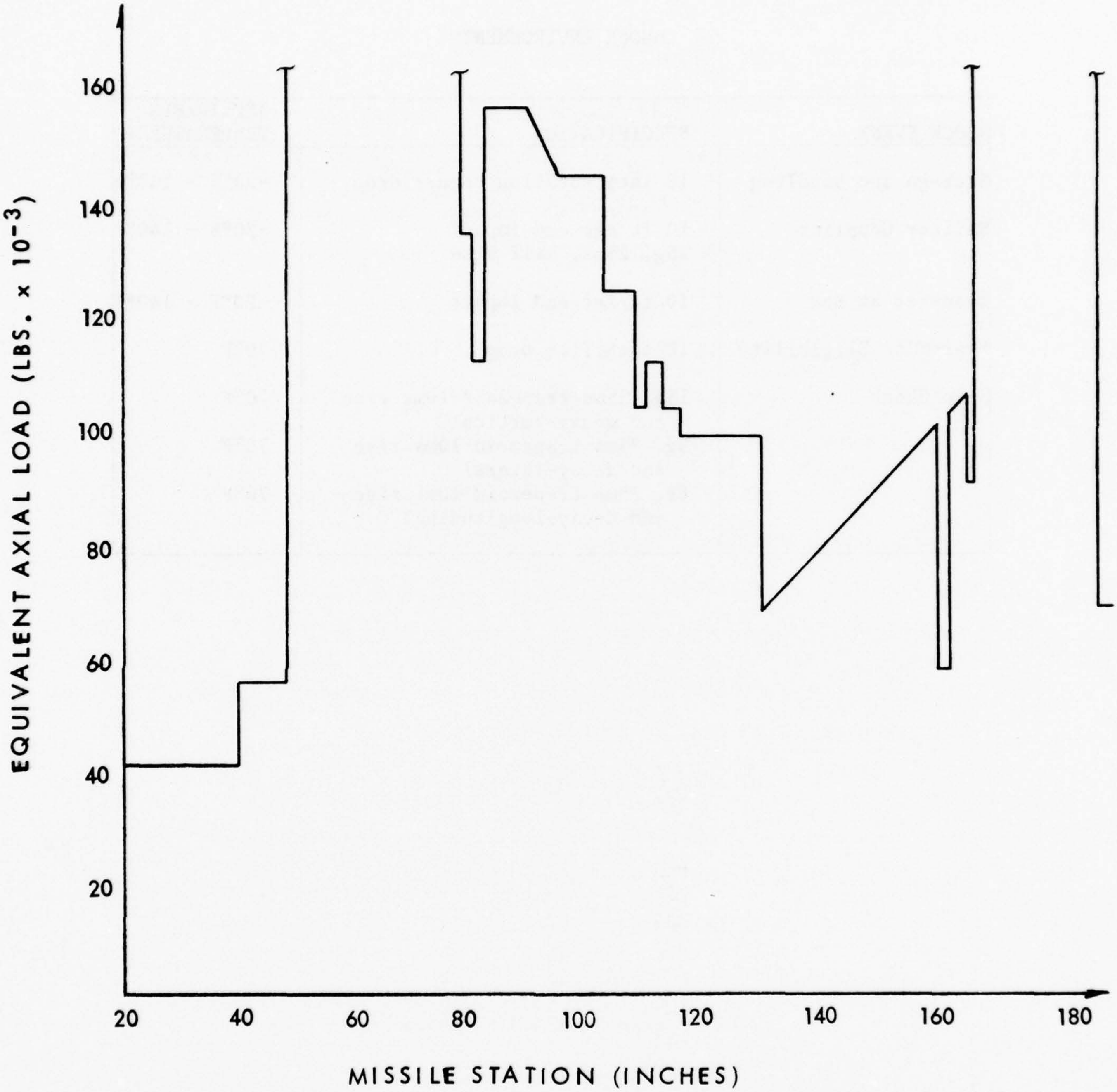


FIGURE 5. HARPOON MISSILE LIMIT EQUIVALENT AXIAL LOAD VERTICAL LOADING WITH SCOOP TO THE SIDE.

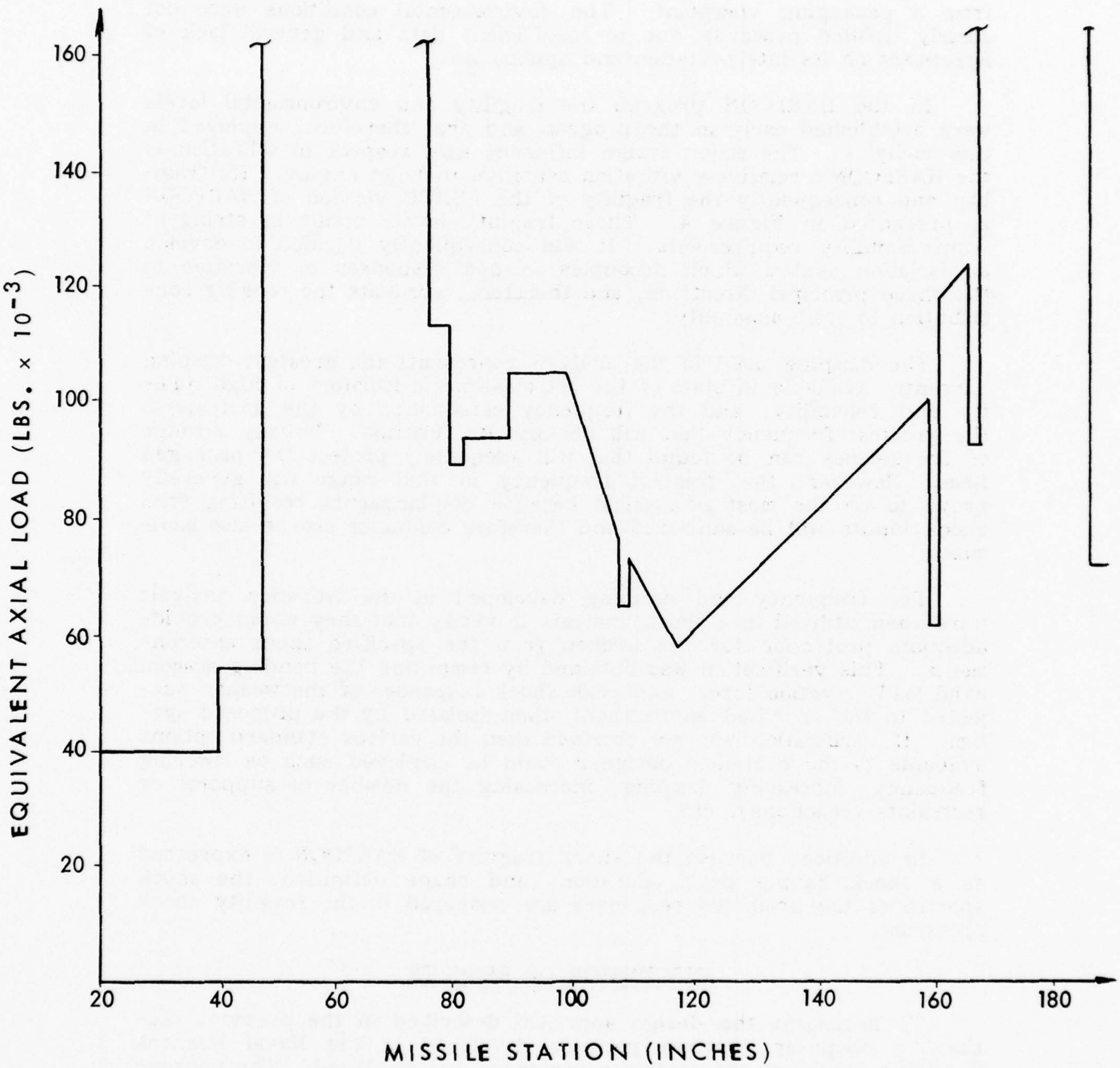


FIGURE 6. HARPOON MISSILE LIMIT EQUIVALENT AXIAL LOAD, TRANSVERSE LOADING WITH SCOOP TO THE SIDE.

handling and transportation logistics and consequently were inadequate from a packaging viewpoint. The environmental conditions were not clearly defined primarily due to insufficient data and general lack of agreement on its interpretation and application.

In the HARPOON program the fragility and environmental levels were established early in the program and are, therefore, employed in this analysis. The major design influence with respect to vibration is the HARPOON's relatively vibration sensitive turbojet engine. Its fragility and consequently the fragility of the ASROC version of HARPOON is presented in Figure 4. These fragility levels result in stringent transmissibility requirements. It was consequently decided to develop an isolation system which decouples weapon responses to vibration in the three principal directions, and therefore, eliminate the rocking contribution to transmissibility.

The damping used in the analysis represents the greatest damping currently available in state of the art elastomeric isolators of high quality and reliability, and the frequency established by the analysis is the greatest frequency that will perform its function. Usually a range of frequencies can be found that will adequately protect the packaged item. However, the greatest frequency in that range will generally prove to be the most economical because displacements resulting from shock inputs will be minimized and therefore container size is also minimized.

The frequency and damping developed in the vibration analysis were then utilized in a shock analysis to verify that they would provide adequate protection for the weapon from the specified shock environments. This verification was obtained by computing the bending moment, axial load, reaction force, and peak shock responses of the weapon subjected to the specified environment when isolated by the proposed system. If verification was not obtained then the various standard options available to the container designer could be employed such as lowering frequency, increasing damping, increasing the number of supports or restraints (reactions), etc.

In addition, because the shock fragility of HARPOON is expressed as a shock having peak, duration, and shape definition, the shock spectra of the predicted responses are compared to the fragility shock spectrum.

DISCUSSION OF RESULTS

To implement the design approach described in the previous section, a computer program package developed at the Naval Weapons Handling Center to aid container designers was employed. The package consists of three programs entitled VIBANL, SHKANL and SPECT which perform, respectively, the vibration, shock and shock spectral analyses required. A single degree of freedom linear oscillator with viscous damping is the mathematical model for the analyses embodied in the

VIBANL and SPECT programs. The SHKANL program uses the same model without damping. This is done to provide a small factor of safety between the predicted and actual performance.

The shock analysis does not include the contribution of cradle weight to the suspended item weight. This contribution is not significant because the cradle weight is a small fraction of the suspended item weight and for most of the analysis embodied in the report, suspended item weight is not a factor in the analysis.

At the present time SHKANL cannot compute shock response to uniform pulses. Structural and displacement responses to the specified uniform pulses are computed using the existing SHKANL routines (flat-drop, side impact, end impact) by computing drop heights/impact velocities which would result in the appropriate deceleration levels.

The analyses resulted in the development of two basic solutions to the isolation system problem for the ASROC version of HARPOON. The detailed results for Solutions 1 and 2, in the form of computer plots and printouts, are presented in Appendices A and B, respectively. Although Appendices A and B contain a complete set of computer printouts, in the body of the report reference will be made only to those required for illustrative purposes.

SOLUTION 1

Solution 1 represents an isolation system having mounts located in the horizontal plane of the CG of the isolated element. In this configuration (See Figure 7) the isolators are loaded in shear in the longitudinal and vertical directions and primarily in tension and compression in the transverse direction.

VIBRATION

Using the maximum available damping of economical shock mounts, 13 percent of critical, and a compression to shear stiffness ratio of 8:1, nominal for typical container mounts, the VIBANL program was executed. VIBANL outputs for Solution 1 are presented in Appendix A and are summarized in Table 2. The natural frequencies as listed in Table 2 were determined to be 19 Hz in the transverse direction and 7 Hz in the vertical and longitudinal directions. Plots of the weapon's response to the specified environment in the three principal directions compared to the weapon's fragility are shown in Figures A-1 through A-3. Although this represents a satisfactory solution to the vibration problem it is noted that the vertical and longitudinal frequency is marginally low, near the range of frequently occurring transportation vibration (2-7 Hz), and in addition will result in relatively large sway space requirements for shock response. In the given physical configuration, the vertical and longitudinal natural frequencies computed, although marginally low, cannot be increased (VIBANL computes the greatest acceptable frequency). Increasing vertical and/or longitudinal natural frequency will

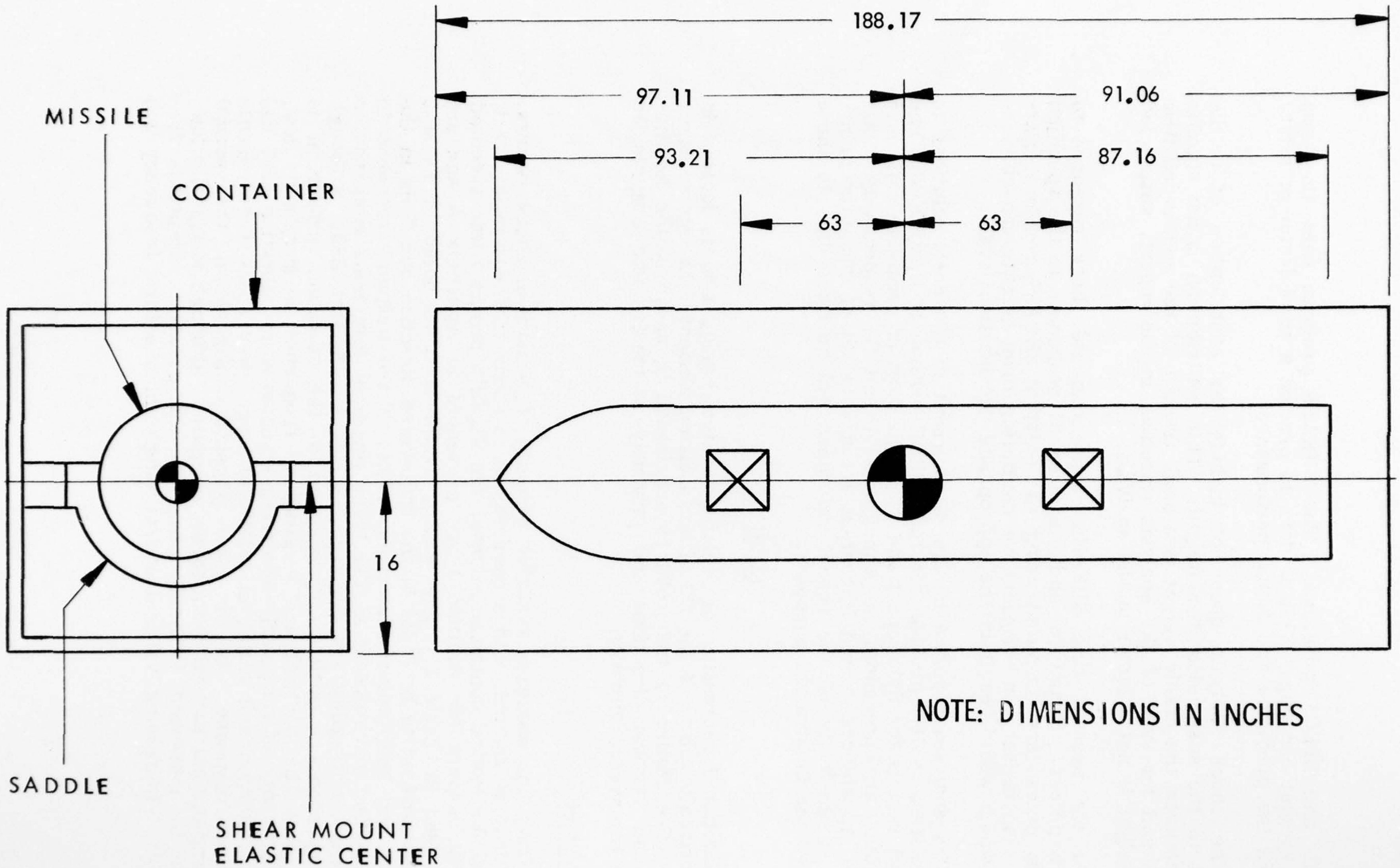


FIGURE 7. SOLUTION 1 ISOLATION SYSTEM CONFIGURATION.

TABLE 2

HARPOON MISSILE ASROC VERSION

VIBRATION SUMMARY (SOLUTIONS 1 AND 2)

	SOLUTION 1			SOLUTION 2		
	DAMP.	FREQ.	RESP.	DAMP.	FREQ.	RESP.
TRANSVERSE	0.13	19	2.86	0.13	19	2.86
VERTICAL	0.13	7	4.97	0.13	10	4.97
LONGITUDINAL	0.13	7	0.91	0.13	10	1.43

cause a corresponding increase in transverse frequency, thereby causing an out of specification response, Figure A-1.

SHOCK

Having determined acceptable isolation system parameters compatible with the vibration environment and weapon design levels, it remains to demonstrate that they provide adequate shock protection. The SHKANL program was used for this purpose. The rotational edgewise drop required container dimensions. Figure 7 and Table A-3 detail the dimensions used in the analysis. The container length was arrived at by considering longitudinal sway space required as a result of longitudinal shocks. The distance from the CG of the suspended mass to the container base was approximated at 16 inches and includes consideration of the radius of the weapon, clearance for the suspended mass cradles that may be required, sway space requirements, and fork pocket clearance. The SHKANL outputs are presented in Appendix A and are summarized in Table 3. A discussion of the significant shock analysis results follows:

Shock Frequency

The isolation system vertical and longitudinal natural frequencies generated by VIBANL were divided by a conversion factor of 1.1 to represent shock frequencies at 70°F. This is an impirical adjustment which accounts for the nonlinearity of typical mounts of comparable stiffness, shape and elastomer subjected to shock induced displacement.

As indicated by Table 1 several of the shock requirements apply at -20°F and +140°F. To account for temperature effects on the shock mounts, nominal thermal stiffness coefficients were used to modify the 70°F shock frequency. The relationships between the shock frequency at 70°F and at the indicated temperature extremes is given below:

at -20°F

$$f_{-20} = \sqrt{1.3}\ f_{70}$$

at 140°F

$$f_{140} = \sqrt{0.9}\ f_{70}$$

TABLE 3
SHOCK SUMMARY (SOLUTION 1)

SHOCK EVENT		DECELERATION (G's)	DISPLACEMENT (INCHES)	MAX. DYNAMIC REACTIONS IN DIRECTION OF SHOCK (LBS. x 10^{-3}) 66.7	136	170	DYNAMIC STRUCTURAL RESPONSE: MAX. BENDING MOMENTS (INCH - LBS. x 10^{-3}) 66.7	136	170	MAX. AXIAL LOADS (LBS. x 10^{-3}) 136	REMARKS
Flat drop 18 inch 70°F		13.3	3.2	11.9		6.2	-106.9		-24.2		Rebound - 4.1 g deceleration; 1 inch displacement. Table A, Figure A-7
End Impact 10 ft./sec.	140°F		3.1								Table A-2, Figures A-8, A-9
	-20°F	14.2			19.5		-8.0	104.7	-1.8	13.8	
Rotational Edge Drop 18 inch 140°F	fwd.		3.4								Table A-3, Figures A-10 thru 15. 126 inches between mounts.
	aft		3.4								
-20°F	fwd.	19.1		11.4		0.3	-127.3		1.4		
	aft	18.8		4.3		7.8	-13.6		-32.8		
25 g 25 ms half sine longitudinal	140°F		3.9								
	-20°F	17.7			24.1		-8.0	129.	-1.8	17.1	Table A-4, Figures A-16, A-17
15 g 35 ms trapezoidal 10 ms rise & decay vertical	70°F	14.4	3.4	12.9		6.7	-115.5		-26.1		Rebound: 4.1 G's, 1.1 inch Table A-5, Figure A-18
9 g 35 ms trapezoidal 10 ms rise & decay transverse	70°F	16.8	0.6	15.0		7.9	-134.7		-30.5		Table A-6, Figure A-19
6 g 35 ms trapezoidal 10 ms rise & decay longitudinal	70°F	5.7	1.4		7.8		-8.0	44.3	-1.8	5.5	Table A-7, Figures A-20, A-21

These coefficients are typical of the thermal effects on the frequency of commonly used shock mounts.

VIBANL yielded vertical and longitudinal vibration frequencies of 7 Hz. Based on the previous discussion the vertical and longitudinal shock frequencies for Solution 1 were computed to be:

$$f_{70} = 6.4 \text{ Hz}$$

$$f_{-20} = 7.3 \text{ Hz}$$

$$f_{140} = 6.1 \text{ Hz}$$

Transverse shock frequency at 70°F was computed as 17.3 Hz.

Shock Level

The maximum predicted deceleration levels in the three primary directions from Table 3 are the 19.1 g response to the -20°F forward edge rotational drop in the vertical direction, 16.8 g response to the 9 g trapezoidal shock in the transverse direction, and 17.7 g response to the 25 g half sine shock in the longitudinal direction. Shock spectra of these deceleration responses were generated and compared to the allowable equipment shock spectrum (42 g, not less than 25 ms, terminal peak sawtooth) using the SPECT program. The comparisons, graphically presented as Figures A-4 through A-6 indicate that the predicted responses are within specification levels. The response to velocity shocks (drops and impacts) is assumed to be a half sine shock having a duration equal to one half the natural shock period of the isolation system in the applicable direction. This is a valid assumption because the excitation duration is short compared to the frequency of the responding system (isolation system). For the responses to acceleration shocks (specified here by half sine or trapezoidal shocks) acceleration time histories were run and the digitized output was used in the SPECT program.

Displacement

Displacement information is used to determine sway space requirements within the container. The largest displacements in the three primary directions as presented in Table 3 are 3.4 inches vertically down, 1.1 inches vertically up, 3.9 inches forward and aft, and .6 inches laterally. These displacement responses result from the 140°F rotational edgewise drops and the 15 g trapezoidal shock in the vertical direction, the 25 g half sine shock in the longitudinal direction, and the 9 g trapezoidal shock in the transverse direction.

Mount spacing is generally determined by consideration of response deceleration or displacement. In this configuration displacement was the driving parameter. The mount spacing was selected to maintain the required sway space within the levels which result from the other shock

requirements. Figures A-10 and A-11 were used to select the appropriate mount spacing.

Structural Response

The structural response parameters of the weapon addressed in this report are weapon bending moments the axial loads. As stated in the design requirements, the design levels for bending and axial loads are combined as limit equivalent axial loads. To combine axial load and bending moment predictions to obtain equivalent axial load data the formula

$$P_{eq} = (2/r)M + P_a = .296\ M + P_a$$

is used, where P_{eq} is the equivalent axial load, r is the radius of the missile (6.75 inches), M is the bending moment, and P_a is the axial load. Figures 5 and 6 show the design levels specified and it can be noted that 40,000 lbs. is the minimum design level at any missile station. Application of the above equation to the peak bending moments and axial loads of Table 3 indicate that only the 25 g half sine longitudinal shock presents a possible problem area. The limit equivalent axial load response to this shock is presented as Figure 8. It can be seen that the response is well within design requirements for the missile.

Reaction Loads

Although no comparison of predicted vertical reaction loads with allowable reaction loads could be made because they occur at designated hard areas for which allowable loads were not provided, they were computed, presented in Table 3, and discussed here. In addition, they will be used by structural designers to determine required section properties of the container cradle. The maximum predicted vertical load at the forward support (MS 66.7) was 12.9 kips resulting from the 15 g trapezoidal shock, while the maximum predicted vertical load at the aft support (MS 170) was 7.8 kips resulting from the aft edge rotational drop at -20°F. The maximum transverse reactions resulted from the 9 g trapezoidal shock and were 15.0 kips at the forward support and 7.9 kips at the aft support.

The maximum allowable reaction at the ASROC restraint shoe (MS 136) is 16.24 kips which the analysis indicated would be exceeded by 7.9 kips in response to the 25 g half sine shock. For this reason additional longitudinal restraint is required. A longitudinal shock analysis incorporating the additional longitudinal restraint was not performed for Solution 1.

COMMENT ON SOLUTION 1

At this point the negative aspects of Solution 1 namely, marginally low vertical and longitudinal vibration frequencies, relatively large sway

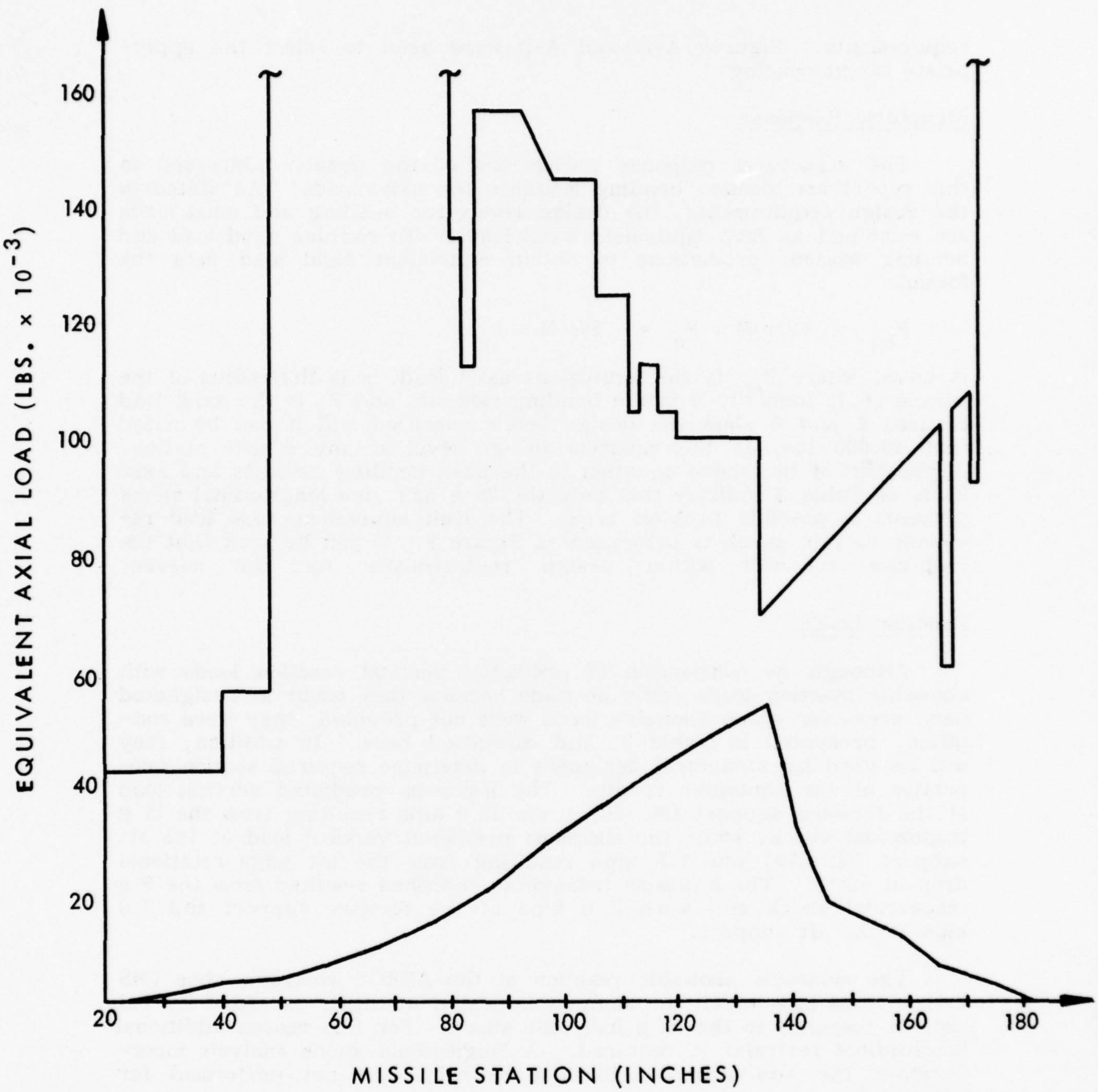


FIGURE 8. EQUIVALENT AXIAL LOAD COMPARISON SOLUTION 1 RESPONSE TO 25G 25MS HALFSINE SHOCK-LONGITUDINAL

space requirements, and the need for additional longitudinal restraint were sufficiently significant to warrant investigation of an alternate solution (Solution 2). The principal objective of an alternate solution is to increase the vertical and longitudinal vibration frequency. Review of Solution 1 vertical vibration and shock responses indicated that vertical frequency could be increased. In addition, since longitudinal friction restraints appear to be required in any solution, the restraint capability could be designed to withstand the force developed by a higher g level due to a higher longitudinal frequency. Solution 1 longitudinal vibration response also indicates greater longitudinal vibration frequency feasibility. Although the review indicated vertical and longitudinal frequencies could be increased, transverse frequency could not. VIBANL computed the greatest allowable transverse vibration frequency for the given damping factor which cannot, therefore, be increased. To effect the frequency adjustments it was decided to decrease the mount compression to shear spring rate ratio. Solution 1 assumed a stiffness ratio of 8:1 and it was determined that, by using offset mounts, the stiffness ratio could be reduced to 4:1. This assumption of a 4:1 stiffness ratio was used for Solution 2.

SOLUTION 2

A sketch of Solution 2 is shown in Figure 9. Here again the mounts are loaded primarily in shear in the longitudinal and vertical directions and in tension and compression in the transverse direction. The damping is 13 percent of critical and the compression to shear stiffness ratio is 4:1.

VIBRATION

Using these parameters VIBANL was run and the results are presented in Table 2. Figures B-1 through B-3 are computed responses of the isolated item to the transportation environment compared to the fragility of the weapon. The vertical and longitudinal frequencies are now 10 Hz, well in the range of recommended vibration frequencies for transportation (7-12 Hz).

SHOCK

It remains to verify that the vibration frequencies determined above are compatible with the shock requirements.

Shock Frequency

The shock frequencies were determined using the formulas given previously and are:

vertical and longitudinal

$$f_{70} = 10/1.1 \text{ Hz} = 9.1 \text{ Hz}$$

$$f_{-20} = \sqrt{1.3}\,(9.1) = 10.4 \text{ Hz}$$

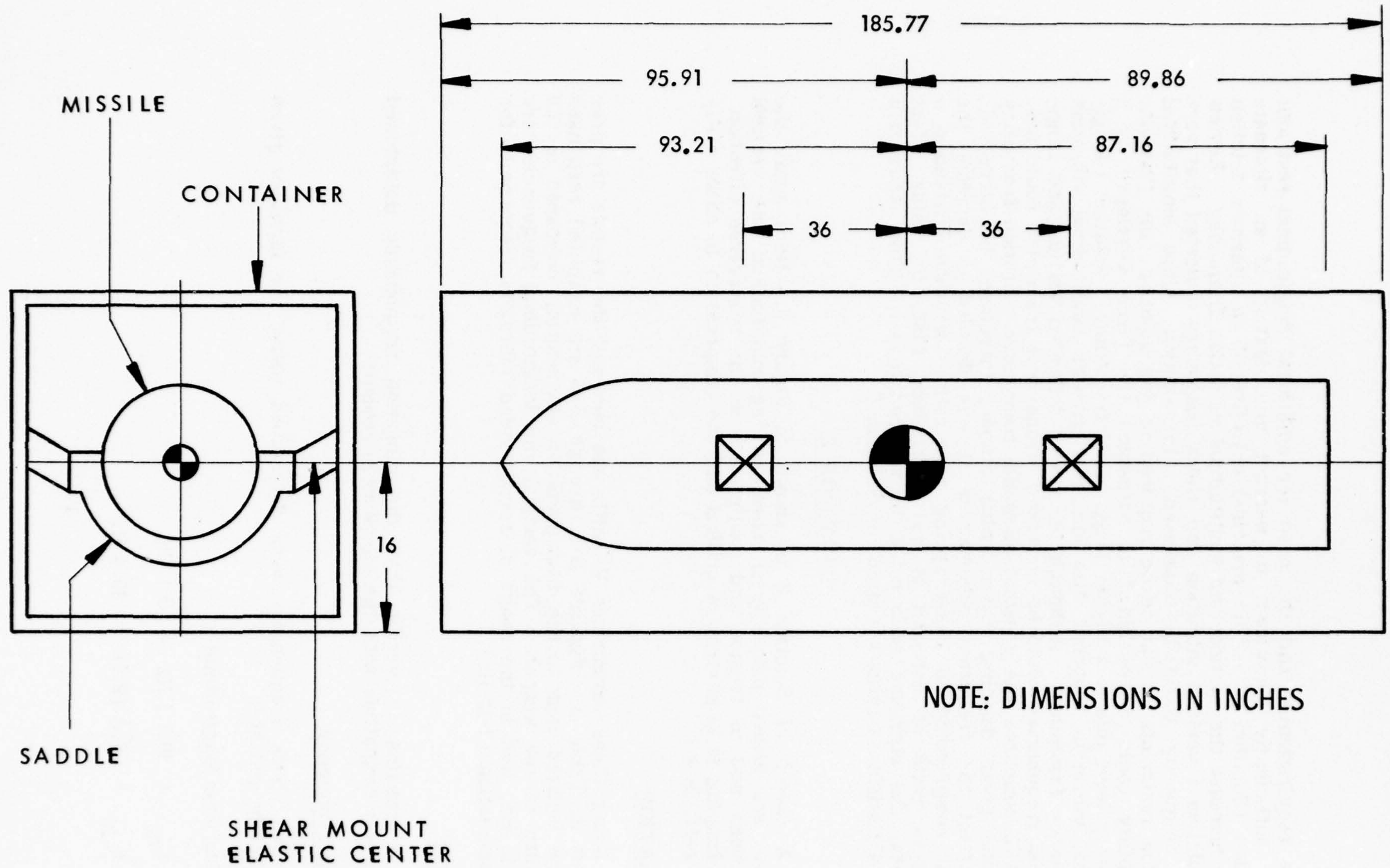


FIGURE 9. SOLUTION 2 ISOLATION SYSTEM CONFIGURATION.

$$f_{140} = \sqrt{.9}\,(9.1) = 8.6 \text{ Hz}$$

transverse

$$f_{70} = 19/1.1 \text{ Hz} = 17.3 \text{ Hz}$$

The SHKANL outputs are presented in Appendix B and summarized in Table 4. The analysis does not include the effects of damping but, if included, there would be reductions of approximately 14 percent in g level and 16 percent in displacement. Damping was not included to provide a factor of safety in the analysis.

Shock Level

The maximum predicted decelerations in the three primary directions as presented in Table 4 were 20.8 g vertical, 16.8 g transverse, and 24.4 g longitudinal. These g levels were developed from the -20°F rotational edgewise drop, the 9 g trapezoidal shock, and the 25 g half sine shock, respectively. The shock spectra generated from these shock events were compared to the specification shock spectrum and, as seen in Figure B-4 and B-6, were within allowable levels.

Displacement

The maximum displacements in the three primary directions are listed in Table 4 and are 3.2 inches vertically down, .7 inches vertically up, 2.7 inches forward and aft, and .6 inches laterally. These displacements occurred as a result of the 140°F rotational edgewise drop, 15 g 35 ms trapezoidal shock, 140°F 25 g, 25 ms half sine shock, and 9 g, 35 ms trapezoidal shock, respectively. There is a 2.4 inch sway space saving in this solution over Solution 1 in the longitudinal direction, .2 inches vertically down and .4 inches vertically up. A larger reduction in sway space in the vertically down direction (up to 1.1 inches) could have been obtained by increasing the mount spacing but this would have made the g levels of the rotational edgewise drop significantly higher than the other shock events although probably within specification. A mount spacing of 72 inches was used which results in deceleration response approximately equal to the greatest vertical deceleration resulting from the other shock events. [See Figures B-10 and B-11]

Structural Response

Because of the higher natural frequency of Solution 2 the equivalent axial loads were higher than Solution 1 but they were still within design levels for all the shocks specified. The most severe case resulted from the 15 g, 35 ms trapezoidal shock and is presented as Figure 10.

TABLE 4
SHOCK SUMMARY (SOLUTION 2)

SHOCK EVENT		DECELERATION (G's)	DISPLACEMENT (INCHES)	DYNAMIC STRUCTURAL RESPONSE: MAX. DYNAMIC REACTIONS IN DIRECTION OF SHOCK (LBS. x 10^{-3}) 66.7	136	170	MAX. BENDING MOMENTS (INCH - LBS. x 10^{-3}) 66.7	136	170	MAX. AXIAL LOADS (LBS. x 10^{-3}) 66.7	136	170	REMARKS
Flat drop 18 inch	70°F	18.5	2.2	16.6		8.7	-148.3		-33.5				Rebound 5.6 G .7 inch Table B-1, Fig. B-7
End Impact 10 ft./sec.	140°F		2.2										9,000 lb. friction at MS 66.7, 170. Table B-2, Figures B-8, B-9
	-20°F	20.3		9.0	9.7	9.0	-8.0	54.1	-1.8	8.9	10.6	5.4	
Rotational Edge Drop 18 inch 140°F	fwd.		3.2										Aft end displacement .5 inches up distance between mounts - 72 inches. Table B-3, Figures B-10, B-15
	aft		3.2										
-20°F	fwd.	20.8		13.9		2.6	-145.6		-8.1				
	aft	20.8		8.3		8.9	-54.1		-36.6				
25 g, 25 ms half sine longitudinal	140°F		2.7										9,000 lb. friction at MS 66.7, 170. Table B-4, Figures A-16, A-17
	-20°F	24.4		9.0	15.2	9.0	-8.0	82.9	-1.8	10.7	14.5	4.7	
15 g 35 ms trapezoid 10 ms rise & decay vertical	70°F	19.4	2.3	17.4		9.1	-156.3		-35.3				Rebound 5.9 g .7 inch Table B-5, Figure B-18
9 g 35 ms trapezoid 10 ms rise & decay transverse	70°F	16.8	0.6	15.5		7.9	-134.7		-30.5				Table B-6, Figure B-19
6 g 35 ms trapezoid 10 ms rise & decay longitudinal	70°F	7.8	0.9	9.0	7.3	9.0	-8.0	-34.6	-1.8	3.4	5.9	7.6	9,000 lb. friction at MS 66.7, 170. Table B-7, Figures B-20, B-21

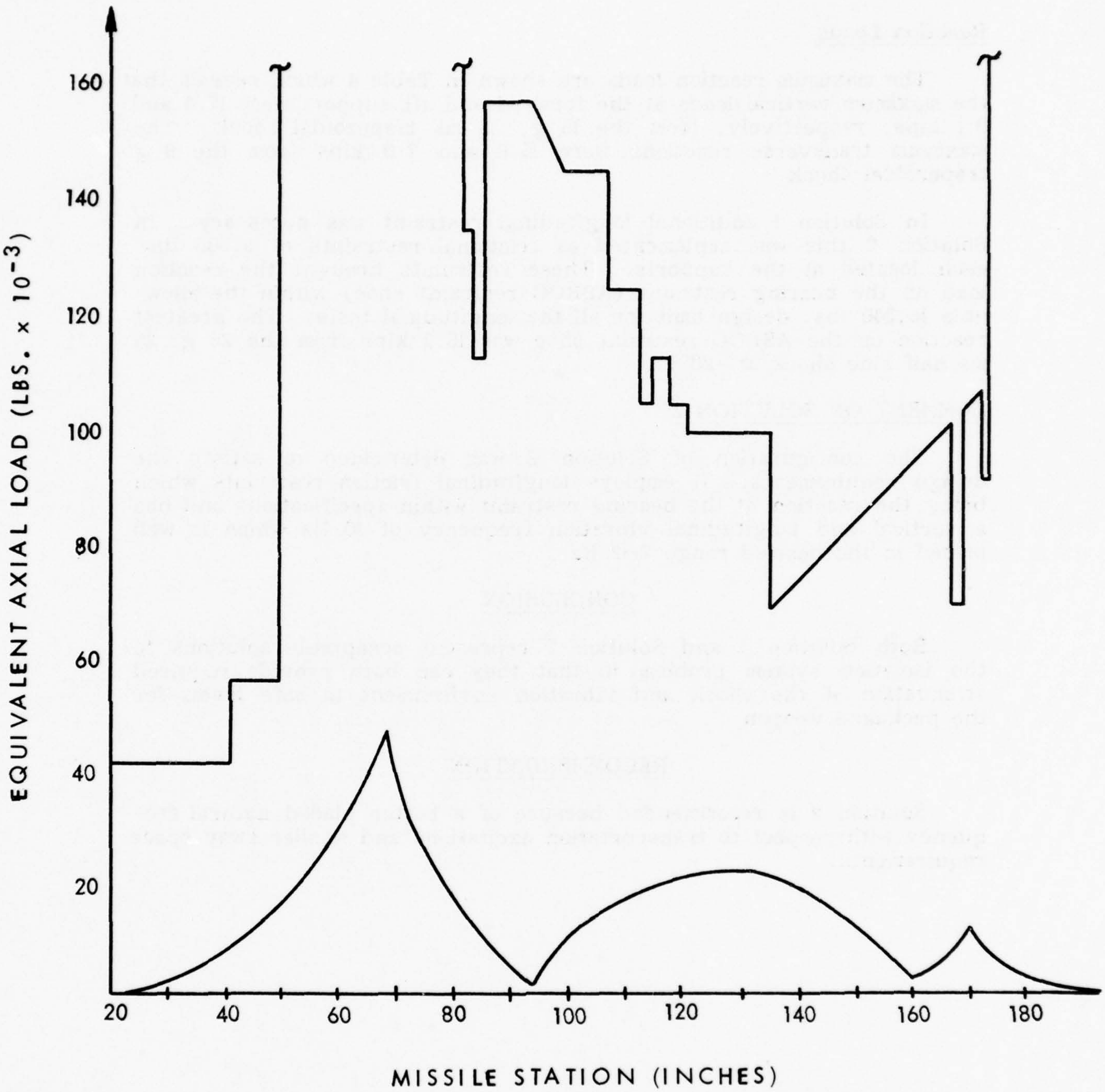


FIGURE 10. EQUIVALENT AXIAL LOAD COMPARISON SOLUTION 2 RESPONSE TO 15G 35MS TRAPEZOIDAL SHOCK-VERTICAL

Reaction Loads

The maximum reaction loads are shown in Table 4 which reveals that the maximum vertical loads at the forward and aft support were 17.4 and 9.1 kips, respectively, from the 15 g, 35 ms trapezoidal shock. The maximum transverse reactions were 15.0 and 7.9 kips from the 9 g trapezoidal shock.

In Solution 1 additional longitudinal restraint was necessary. In Solution 2 this was implemented as frictional restraints of 9,000 lbs. each located at the supports. These restraints brought the reaction load on the bearing restraint (ASROC restraint shoe) within the allowable 16,240 lbs. design limit for all the longitudinal tests. The greatest reaction on the ASROC restraint shoe was 15.2 kips from the 25 g, 25 ms half sine shock at -20°F.

COMMENT ON SOLUTION 2

The configuration of Solution 2 was determined to satisfy the design requirements. It employs longitudinal friction restraints which bring the reaction at the bearing restraint within specifications and has a vertical and longitudinal vibration frequency of 10 Hz which is well placed in the desired range 7-12 Hz.

CONCLUSION

Both Solution 1 and Solution 2 represent acceptable solutions to the isolation system problem in that they can both provide required attenuation of the shock and vibration environment to safe levels for the packaged weapon.

RECOMMENDATION

Solution 2 is recommended because of a better placed natural frequency with respect to transportation excitations and smaller sway space requirements.

APPENDIX A

GLOSSARY OF TERMS USED

IN COMPUTER PRINTOUTS

ADC	DECELERATION- AFT EDGE DROP	G'S
ADS	DISPLACEMENT- AFT EDGE DROP	INCHES
AXL	AXIAL LOAD	POUNDS
DYM	DYNAMIC BENDING MOMENT	INCH-POUNDS
F	FREQUENCY	HERTZ
FDC	DECELERATION- FORWARD EDGE DROP	G'S
FDS	DISPLACEMENT- FORWARD EDGE DROP	INCHES
FR	FRAGILITY	G'S
FREQ	FREQUENCY	HERTZ
IR	ITEM RESPONSE TO FREQUENCY	G'S
IS	ITEM STATION	INCHES
RESP	RESPONSE SHOCK SPECTRUM	G'S
SPAC	HALF MOUNT SPACING	INCHES
SPEC	SPECIFICATION SHOCK SPECTRUM	G'S

FIGURE A-1

TRANSVERSE ANALYSIS

PLOT OF FRAGILITY AND ITEM RESPONSE VERSUS FREQUENCY

FRAGILITY(FR) = +

ITEM RESPONSE(IR) = *

```
     F    FR    IR 0.0                                             5.0
    HZ     G     G +-------------------------------------------------+
   5.0  5.00  1.40 I             *                                   +
   6.0  5.00  1.39 I             *                                   +
   7.0  5.00  1.44 I             *                                   +
   8.0  5.00  1.52 I              *                                  +
   9.0  5.00  1.15 I          *                                      +
  10.0  5.00  0.89 I        *                                        +
  11.0  5.00  0.96 I        *                                        +
  12.0  5.00  1.06 I         *                                       +
  13.0  5.00  1.21 I           *                                     +
  14.0  5.00  1.44 I             *                                   +
  15.0  5.00  1.67 I               *                                 +
  16.0  5.00  2.02 I                   *                             +
  17.0  5.00  2.41 I                        *                        +
  18.0  5.00  2.78 I                           *                     +
  19.0  5.00  2.86 I                            *                    +
  20.0  3.00  2.82 I                            *+
  21.0  3.00  2.52 I                        *    +
  22.0  3.00  2.18 I                    *        +
  23.0  3.00  1.96 I                  *          +
  24.0  3.00  1.78 I                *            +
  25.0  2.00  1.64 I               *   +
  26.0  2.00  0.79 I       *           +
  27.0  2.00  0.74 I      *            +
  28.0  2.00  0.69 I      *            +
  29.0  2.00  0.66 I     *             +
  30.0  2.00  0.63 I     *             +
  31.0  2.00  0.60 I     *             +
  32.0  2.00  0.60 I     *             +
  33.0  2.00  0.58 I     *             +
  34.0  2.00  0.38 I   *               +
  35.0  2.00  0.35 I  *                +
  36.0  2.00  0.33 I  *                +
  37.0  2.00  0.31 I  *                +
  38.0  2.00  0.30 I  *                +
  39.0  2.00  0.28 I  *                +
  40.0  2.00  0.26 I  *                +
  50.0  2.00  0.20 I *                 +
  60.0  2.00  0.20 I *                 +
  70.0  2.00  0.18 I *                 +
  80.0  2.00  0.16 I *                 +
  90.0  2.00  0.15 I*                  +
 100.0  0.25  0.14 I*+
 150.0  0.25  0.13 I*+
 200.0  0.25  0.11 I*+
 250.0  2.00  0.09 I*                  +
 300.0  2.00  0.07 I*                  +
 350.0  2.00  0.07 I*                  +
 400.0  2.00  0.06 I*                  +
 500.0  2.00  0.03 *                   +
```

FIGURE A-2

VERTICAL ANALYSIS
PLOT OF FRAGILITY AND ITEM RESPONSE VERSUS FREQUENCY
FRAGILITY(FR) = +
ITEM RESPONSE(IR) = *

```
    F    FR    IR 0.0                                              5.0
   HZ     G     G +-------------------------------------------------+
  5.0  5.00  3.40 I                                 *               +
  6.0  5.00  3.70 I                                    *            +
  7.0  5.00  4.97 I                                                 $
  8.0  5.00  3.06 I                              *                  +
  9.0  5.00  1.80 I                 *                               +
 10.0  5.00  1.21 I           *                                     +
 11.0  5.00  0.89 I        *                                        +
 12.0  5.00  0.69 I      *                                          +
 13.0  5.00  0.40 I   *                                             +
 14.0  5.00  0.26 I  *                                              +
 15.0  5.00  0.22 I *                                               +
 16.0  5.00  0.20 I *                                               +
 17.0  5.00  0.17 I *                                               +
 18.0  5.00  0.15 I *                                               +
 19.0  5.00  0.14 I*                                                +
 20.0  3.00  0.14 I*                            +
 21.0  3.00  0.14 I*                            +
 22.0  3.00  0.14 I*                            +
 23.0  3.00  0.14 I*                            +
 24.0  3.00  0.14 I*                            +
 25.0  2.00  0.14 I*                  +
 26.0  2.00  0.08 I*                  +
 27.0  2.00  0.08 I*                  +
 28.0  2.00  0.08 I*                  +
 29.0  2.00  0.08 I*                  +
 30.0  2.00  0.08 I*                  +
 31.0  2.00  0.08 I*                  +
 32.0  2.00  0.08 I*                  +
 33.0  2.00  0.08 I*                  +
 34.0  2.00  0.05 I*                  +
 35.0  2.00  0.05 I*                  +
 36.0  2.00  0.05 I*                  +
 37.0  2.00  0.05 *                   +
 38.0  2.00  0.05 *                   +
 39.0  2.00  0.05 *                   +
 40.0  2.00  0.05 *                   +
 50.0  2.00  0.04 *                   +
 60.0  2.00  0.05 *                   +
 70.0  2.00  0.05 *                   +
 80.0  2.00  0.04 *                   +
 90.0  2.00  0.04 *                   +
100.0  0.25  0.04 * +
150.0  0.25  0.04 * +
200.0  0.25  0.04 * +
250.0  2.00  0.03 *                   +
300.0  2.00  0.02 *                   +
350.0  2.00  0.03 *                   +
400.0  2.00  0.02 *                   +
500.0  2.00  0.01 *                   +
```

FIGURE A-3

LONGITUDINAL ANALYSIS
PLOT OF FRAGILITY AND ITEM RESPONSE VERSUS FREQUENCY
FRAGILITY(FR) = +
ITEM RESPONSE(IR) = *

```
    F    FR     IR 0.0                                              2.0
   HZ     G      G +-------------------------------------------------+
  5.0  2.00  0.21 I    *                                            +
  6.0  2.00  0.47 I           *                                     +
  7.0  2.00  0.91 I                     *                           +
  8.0  2.00  0.73 I                 *                               +
  9.0  2.00  0.47 I           *                                     +
 10.0  2.00  0.35 I        *                                        +
 11.0  2.00  0.27 I      *                                          +
 12.0  2.00  0.25 I     *                                           +
 13.0  2.00  0.24 I     *                                           +
 14.0  2.00  0.22 I    *                                            +
 15.0  2.00  0.22 I    *                                            +
 16.0  2.00  0.14 I  *                                              +
 17.0  2.00  0.14 I  *                                              +
 18.0  2.00  0.14 I  *                                              +
 19.0  2.00  0.14 I  *                                              +
 20.0  2.00  0.14 I  *                                              +
 21.0  2.00  0.14 I  *                                              +
 22.0  2.00  0.14 I  *                                              +
 23.0  2.00  0.14 I  *                                              +
 24.0  2.00  0.14 I  *                                              +
 25.0  2.00  0.14 I   *                                             +
 26.0  2.00  0.08 I *                                               +
 27.0  2.00  0.08 I *                                               +
 28.0  2.00  0.08 I *                                               +
 29.0  2.00  0.08 I *                                               +
 30.0  2.00  0.08 I *                                               +
 31.0  2.00  0.08 I *                                               +
 32.0  2.00  0.08 I *                                               +
 33.0  2.00  0.08 I *                                               +
 34.0  2.00  0.04 I*                                                +
 35.0  2.00  0.04 I*                                                +
 36.0  2.00  0.04 I*                                                +
 37.0  2.00  0.04 I*                                                +
 38.0  2.00  0.05 I*                                                +
 39.0  2.00  0.05 I*                                                +
 40.0  2.00  0.05 I*                                                +
 50.0  2.00  0.04 I*                                                +
 60.0  2.00  0.05 I*                                                +
 70.0  2.00  0.05 I*                                                +
 80.0  2.00  0.04 I*                                                +
 90.0  2.00  0.04 I*                                                +
100.0  0.25  0.04 I*    +
150.0  0.25  0.04 I*    +
200.0  0.25  0.04 I*    +
250.0  2.00  0.03 I*                                                +
300.0  2.00  0.02 I*                                                +
350.0  2.00  0.03 I*                                                +
400.0  2.00  0.02 I*                                                +
500.0  2.00  0.01 *                                                 +
```

FIGURE A-4

COMPARISON OF 42G, 25MS TPS (SPECIFICATION) TO 19.1G, 68MS HALFSINE FROM -20°F FORWARD EDGE DROP (RESPONSE)

SHOCK SPECTRUM

SPECIFICATION = *

RESPONSE = +

FREQ HZ	SPEC G	RESP G
2.	6.5	10.3
4.	12.8	19.5
6.	19.0	26.7
8.	24.9	31.3
10.	30.3	33.4
14.	39.7	33.5
18.	46.7	31.4
22.	51.0	28.8
26.	52.5	26.3
30.	51.8	24.0
34.	48.4	22.0
38.	44.2	21.3
42.	40.0	22.2
46.	37.3	22.5
50.	36.7	22.5
60.	42.0	21.4
70.	45.8	20.9
80.	42.0	21.1
90.	39.0	20.7
100.	42.0	20.5
110.	44.4	20.6
120.	42.0	20.2
130.	39.9	20.2
140.	42.0	20.3
150.	43.7	20.1

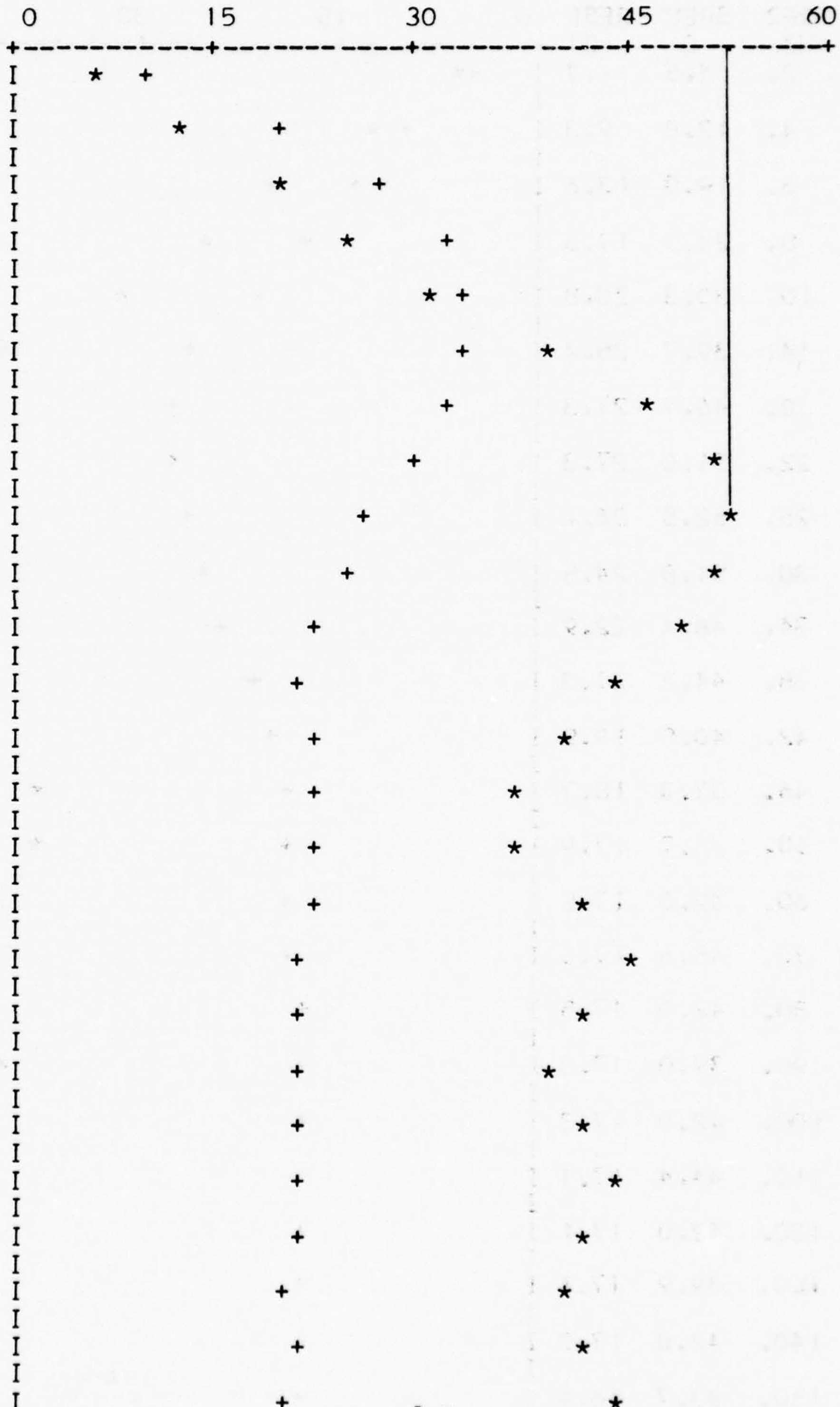


FIGURE A-5

COMPARISON OF 42G, 25MS TPS (SPECIFICATION) TO RESPONSE TO 9G, 35MS TRAPEZOIDAL SHOCK (RESPONSE)

SHOCK SPECTRUM
SPECIFICATION = *
RESPONSE = +

FREQ HZ	SPEC G	RESP G
2.	6.5	4.7
4.	12.8	9.3
6.	19.0	13.6
8.	24.9	17.5
10.	30.3	20.8
14.	39.7	25.4
18.	46.7	27.3
22.	51.0	27.3
26.	52.5	26.1
30.	51.8	24.5
34.	48.4	22.9
38.	44.2	21.3
42.	40.0	19.9
46.	37.3	18.7
50.	36.7	17.9
60.	42.0	17.8
70.	45.8	17.8
80.	42.0	17.5
90.	39.0	17.3
100.	42.0	17.3
110.	44.4	17.1
120.	42.0	17.1
130.	39.9	17.1
140.	42.0	17.0
150.	43.7	16.9

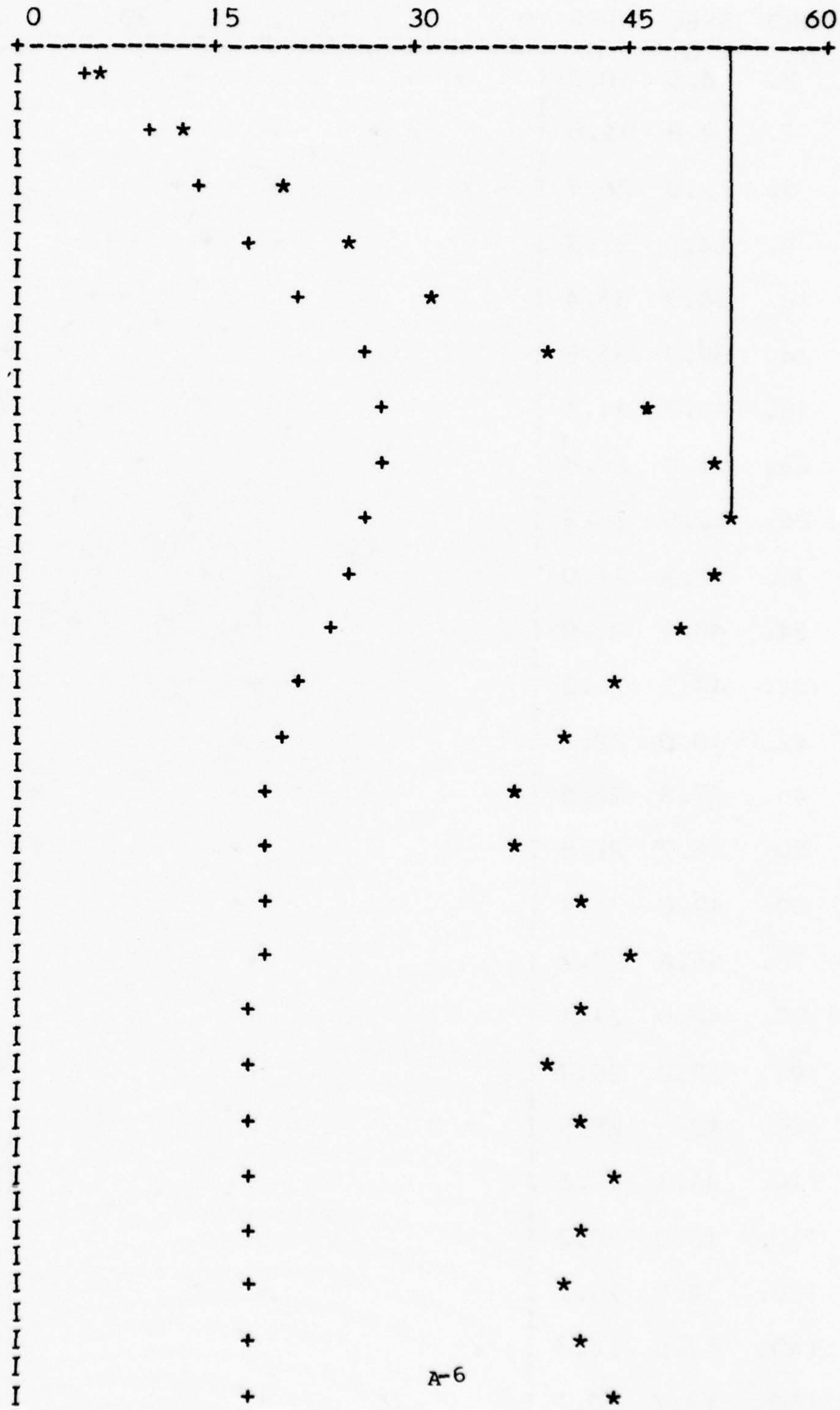


FIGURE A-6

COMPARISON OF 42G, 25MS TPS (SPECIFICATION) TO RESPONSE TO 25G, 25MS HALFSINE SHOCK (RESPONSE)

SHOCK SPECTRUM

SPECIFICATION = *

RESPONSE = +

FREQ HZ	SPEC G	RESP G
2.	6.5	9.6
4.	12.8	18.2
6.	19.0	24.8
8.	24.9	28.8
10.	30.3	30.4
14.	39.7	30.0
18.	46.7	27.6
22.	51.0	24.9
26.	52.5	22.4
30.	51.8	20.2
34.	48.4	18.5
38.	44.2	18.0
42.	40.0	18.5
46.	37.3	18.6
50.	36.7	18.4
60.	42.0	17.9
70.	45.8	17.9
80.	42.0	17.7
90.	39.0	17.8
100.	42.0	17.7
110.	44.4	17.8
120.	42.0	17.7
130.	39.9	17.7
140.	42.0	17.7
150.	43.7	17.7

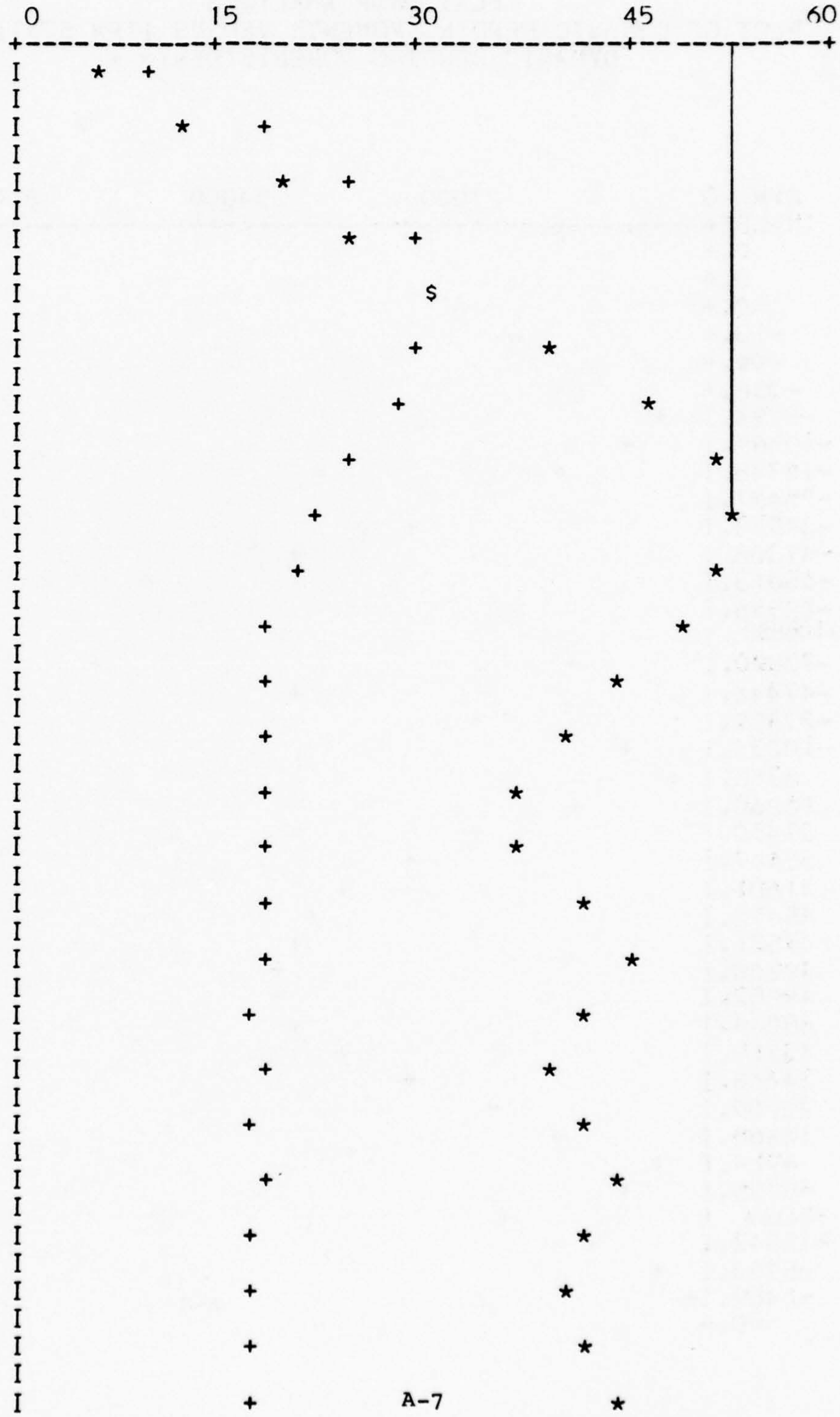


FIGURE A-7

FLAT DROP ANALYSIS

PLOT OF DYNAMIC BENDING MOMENTS VERSUS ITEM STATIONS

DYNAMIC BENDING MOMENTS(DYM)= +

Scale (IN-LBS): 0, 27000, 54000, 81000, 108000

IS IN	DYM IN-LBS
0	0.
5	0.
10	0.
15	-13.
19	-99.
24	-358.
29	-5294.
34	-10585.
39	-16748.
44	-25497.
49	-34573.
54	-47306.
58	-65613.
63	-88536.
66.7	-106880.
73	-70890.
78	-47446.
83	-27359.
88	-10236.
93	3758.
97	16260.
102	27450.
107	35467.
112	41601.
117	45678.
122	48521.
127	49860.
132	49852.
136	48044.
141	43219.
146	34668.
151	25900.
156	16488.
161	4914.
166	-8905.
170	-24169
175	-12842.
180	-5763.
185	-1489.
190	-0.

TABLE A-1

FLAT DROP-HARPOON MISSILE ASROC VERSION SOLUTION 1

INPUT PARAMETERS

SUPPORT LOCATIONS(IS)	FWD	66.70
	AFT	170.00
VERTICAL SHOCK FREQ		6.40 HZ
DROP HEIGHT		18.00 INS
WEIGHT OF THE CONTAINER SHELL		600.00 LBS

RESULTS

PRIMARY-		
DISPLACEMENT		3.18 INS
DECELERATION		13.31 G
REBOUND-		
DISPLACEMENT		0.97 INS
DECELERATION		4.06 G
DYNAMIC SUPPORT REACTIONS	FWD	11929.64 LBS
	AFT	6238.29 LBS
DYNAMIC BENDING MOMENTS	FWD	-106880.52 IN-LBS
	AFT	-24169.63 IN-LBS

REMARKS

TABLE A-2

END IMPACT-HARPOON MISSILE ASROC VERSION SOLUTION 1

INPUT PARAMETERS

SUPPORT LOCATIONS(IS)	FWD	66.70
	AFT	170.00
LONGITUDINAL SHOCK FREQUENCY-HIGH TEMPERATURE		6.10 HZ
	LOW TEMPERATURE	7.30 HZ
IMPACT VELOCITY		10.00 FPS
NUMBER OF LONGITUDINAL BEARING RESTAINTS		1
LOCATION OF LONG BEARING RESTRAINTS(IS)		136.00
ECCENTRICITIES		7.75 INS

RESULTS

DISPLACEMENT		3.13 INS
DECELERATION		14.24 G
DYNAMIC SUPPORT REACTIONS	FWD	2354.97 LBS
	AFT	-989.89 LBS
DYNAMIC BENDING MOMENTS	FWD	-8030.66 IN-LBS
	AFT	-1816.03 IN-LBS

DYNAMIC BENDING MOMENTS AT LONGITUDINAL RESTRAINTS

1ST BEARING RESTRAINT	104720.04	-45954.52 IN-LBS

REMARKS

FIGURE A-8
ITEM DYNAMIC MOMENTS
END IMPACT ANALYSIS
IMPACT VELOCITY 10.00 FEET PER SECOND

IS IN	DYM IN-LBS
0	0.
5	0.
10	0.
15	-1.
19	-7.
24	-27.
29	-398.
34	-795.
39	-1258.
44	-1916.
49	-2598.
54	-3554.
58	-4930.
63	-6652.
68	-5145.
73	3975.
78	12843.
83	21458.
88	29851.
93	38008.
97	46053.
102	54000.
107	61709.
112	69276.
117	76688.
122	84008.
127	91214.
132	98320.
136	104720
141	-38641.
146	-32177.
151	-25730.
156	-19331.
161	-13095.
166	-7027.
171	-2093.
175	-965.
180	-433.
185	-112.
190	0.

Scale: 0, 27000, 54000, 81000, 108000

FIGURE A-9
ITEM AXIAL LOADS
END IMPACT ANALYSIS
IMPACT VELOCITY 10.00 FEET PER SECOND

IS IN	AXL LBS
0	0.
5	1.
10	1.
15	9.
19	36.
24	523.
29	1152.
34	1175.
39	1891.
44	1941.
49	2258.
54	3417.
58	4531.
63	5516.
68	6454.
73	7248.
78	7982.
83	8691.
88	9345.
93	9909.
97	10144.
102	10652.
107	11207.
112	11671.
117	11989.
122	12332.
127	12644.
132	12888.
136	13751
141	-5182.
146	-4769.
151	-4734.
156	-4378.
161	-3890.
166	-3238.
171	-2559.
175	-1888.
180	-1223.
185	-612.
190	-98.

FIGURE A-10

PLOT OF DECELERATION VS.
HALF-MOUNTSPACING
FOREWARD DROP=+ AFT DROP=*
(LOW TEMPERATURE)

SPAC IN	FDC G	ADC G
10	10.20	10.49
12	10.56	10.82
14	10.92	11.16
16	11.28	11.50
19	11.64	11.84
21	12.01	12.18
23	12.37	12.51
25	12.73	12.85
27	13.09	13.19
29	13.45	13.53
32	13.81	13.86
34	14.18	14.20
36	14.54	14.54
38	14.90	14.88
40	15.26	15.21
42	15.62	15.55
44	15.98	15.89
47	16.35	16.23
49	16.71	16.57
51	17.07	16.90
53	17.43	17.24
55	17.79	17.58
57	18.16	17.92
60	18.52	18.25
62	18.88	18.59
64	19.24	18.93
66	19.60	19.27
68	19.96	19.61
70	20.33	19.94
73	20.69	20.28
75	21.05	20.62
77	21.41	20.96
79	21.77	21.29
81	22.13	21.63
83	22.50	21.97
85	22.86	22.31
88	23.22	22.64
90	23.58	22.98
92	23.94	23.32
94	24.31	23.66

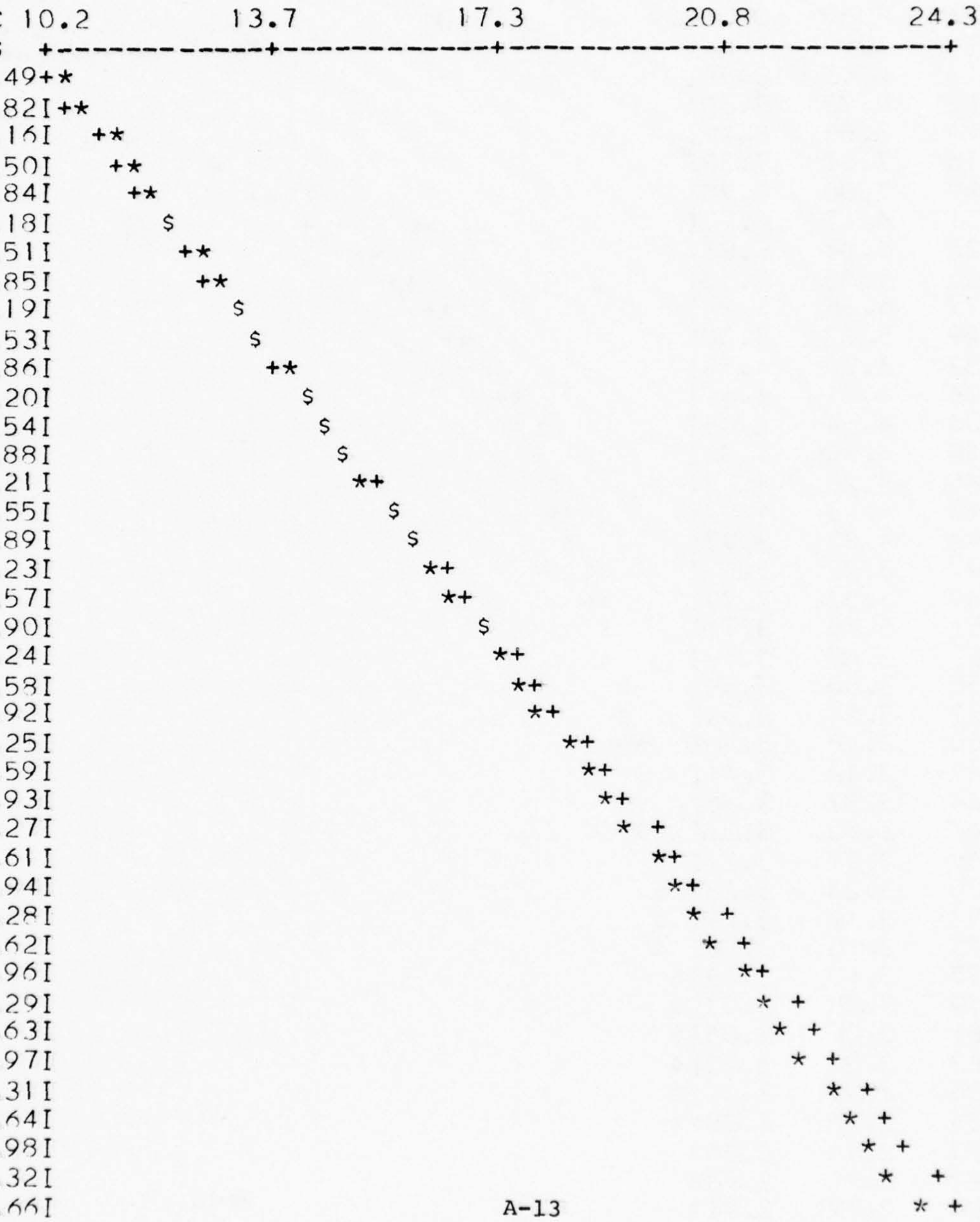


FIGURE A-11

PLOT OF DISPLACEMENT VS
HALF-MOUNT SPACING
FOREWARD DROP=+ AFT DROP=*
(HIGH TEMPERATURE)

SPAC IN	FDS INS	ADS INS
10	11.43	10.88
12	9.73	9.30
14	8.55	8.19
16	7.67	7.38
19	7.00	6.75
21	6.47	6.25
23	6.04	5.85
25	5.68	5.52
27	5.38	5.24
29	5.12	5.00
32	4.90	4.79
34	4.71	4.61
36	4.54	4.45
38	4.39	4.31
40	4.25	4.18
42	4.13	4.07
44	4.02	3.97
47	3.92	3.87
49	3.83	3.79
51	3.75	3.71
53	3.67	3.64
55	3.60	3.58
57	3.54	3.52
60	3.48	3.46
62	3.42	3.41
64	3.37	3.36
66	3.32	3.31
68	3.27	3.27
70	3.23	3.23
73	3.19	3.19
75	3.15	3.16
77	3.12	3.12
79	3.08	3.09
81	3.05	3.06
83	3.02	3.03
85	2.99	3.01
88	2.96	2.98
90	2.94	2.96
92	2.91	2.93
94	2.89	2.91

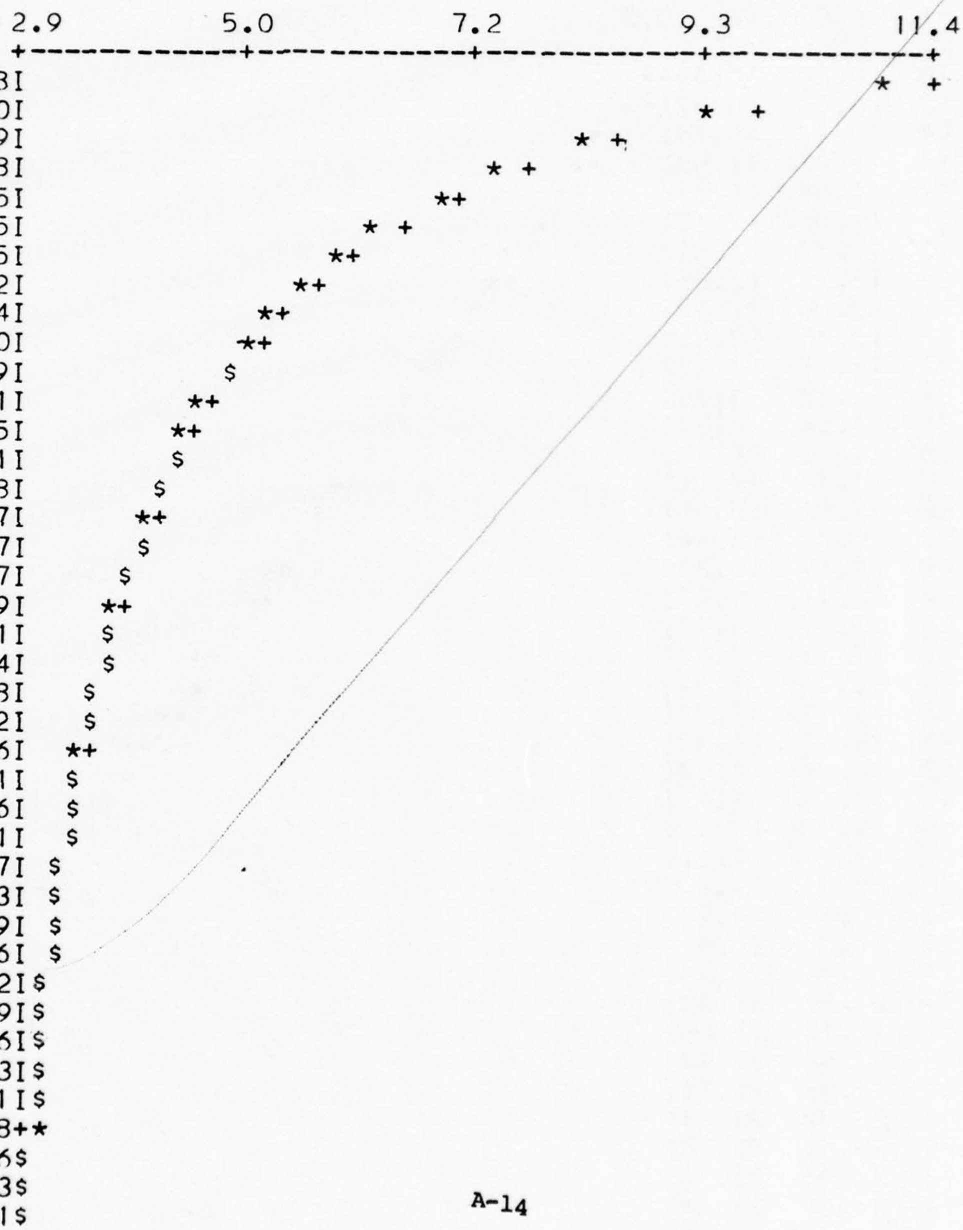


TABLE A-3

ROTATIONAL EDGEWISE DROP
HARPOON MISSILE ASROC VERSION

INPUT PARAMETERS

HALF MOUNT SPACING		63.00	INS
SUPPORT LOCATIONS(IS)	FWD	66.70	
	AFT	170.00	
OVERALL CONTAINER LENGTH		188.17	INS
ITEM PITCH MOMENT OF INERTIA		9168.00	IN-LB-SECSQ
DISTANCE ITEM C.G. TO CONT BASE		16.00	INS
DISTANCE ITEM C.G. TO CONT FORWARD END		97.11	INS
DROP HEIGHT		18.00	INS
VERTICAL FREQUENCY-LOW TEMPERATURE		7.30	HZ
VERTICAL FREQUENCY-HIGH TEMPERATURE		6.10	HZ
LOCATION FOR DEC CALCULATIONS-FORWARD		9.63	(IS)
LOCATION FOR DEC CALCULATIONS-AFT		190.00	(IS)
LOCATION FOR DSPL CALCULATIONS-FORWARD		9.63	(IS)
LOCATION FOR DSPL CALCULATIONS-AFT		190.00	(IS)

RESULTS

AT LOW TEMPERATURE

FORWARD EDGE DROP

MAXIMUM DECELERATION AT(IS)	9.63	19.09	G
DYNAMIC SUPPORT REACTIONS	FWD	11356.22	LBS
	AFT	272.75	LBS
DYN BENDING MOM AT SUPPORTS-	FWD	-127376.56	IN-LBS
	AFT	1359.63	IN-LBS

AFT EDGE DROP

MAXIMUM DECELERATION AT(IS)	190.00	18.79	G
DYNAMIC SUPPORT REACTIONS	FWD	4336.20	LBS
	AFT	7840.54	LBS
DYN BENDING MOM AT SUPPORTS-	FWD	-13634.73	IN-LBS
	AFT	-32754.26	IN-LBS

AT HIGH TEMPERATURE

FWD EDGE DROP DISPLACEMENT AT(IS)	3.39
AFT EDGE DROP DISPLACEMENT AT(IS)	3.38

FIGURE A-12

PLOT OF DECELERATION AT ITEM STATIONS
FOR HALF-MOUNT SPACING 63.0 INCHES
FOREWARD DROP=+ AFT DROP=*
(LOW TEMPERATURE)

IS IN	FDC G	ADC G
0	20.19	-2.56
5	19.63	-2.01
10	19.08	-1.46
15	18.52	-0.92
19	17.96	-0.37
24	17.41	0.18
29	16.85	0.72
34	16.29	1.27
39	15.74	1.82
44	15.18	2.37
49	14.62	2.91
*4	14.07	3.46
58	13.51	4.01
63	12.96	4.56
68	12.40	5.10
73	11.84	5.65
78	11.29	6.20
83	10.73	6.75
88	10.17	7.29
93	9.62	7.84
97	9.06	8.39
102	8.50	8.94
107	7.95	9.48
112	7.39	10.03
117	6.83	10.58
122	6.28	11.13
127	5.72	11.67
132	5.16	12.22
136	4.61	12.77
141	4.05	13.31
146	3.49	13.86
151	2.94	14.41
156	2.38	14.96
161	1.83	15.50
166	1.27	16.05
171	0.71	16.60
175	0.16	17.15
180	-0.40	17.69
185	-0.96	18.24
190	-1.51	18.79

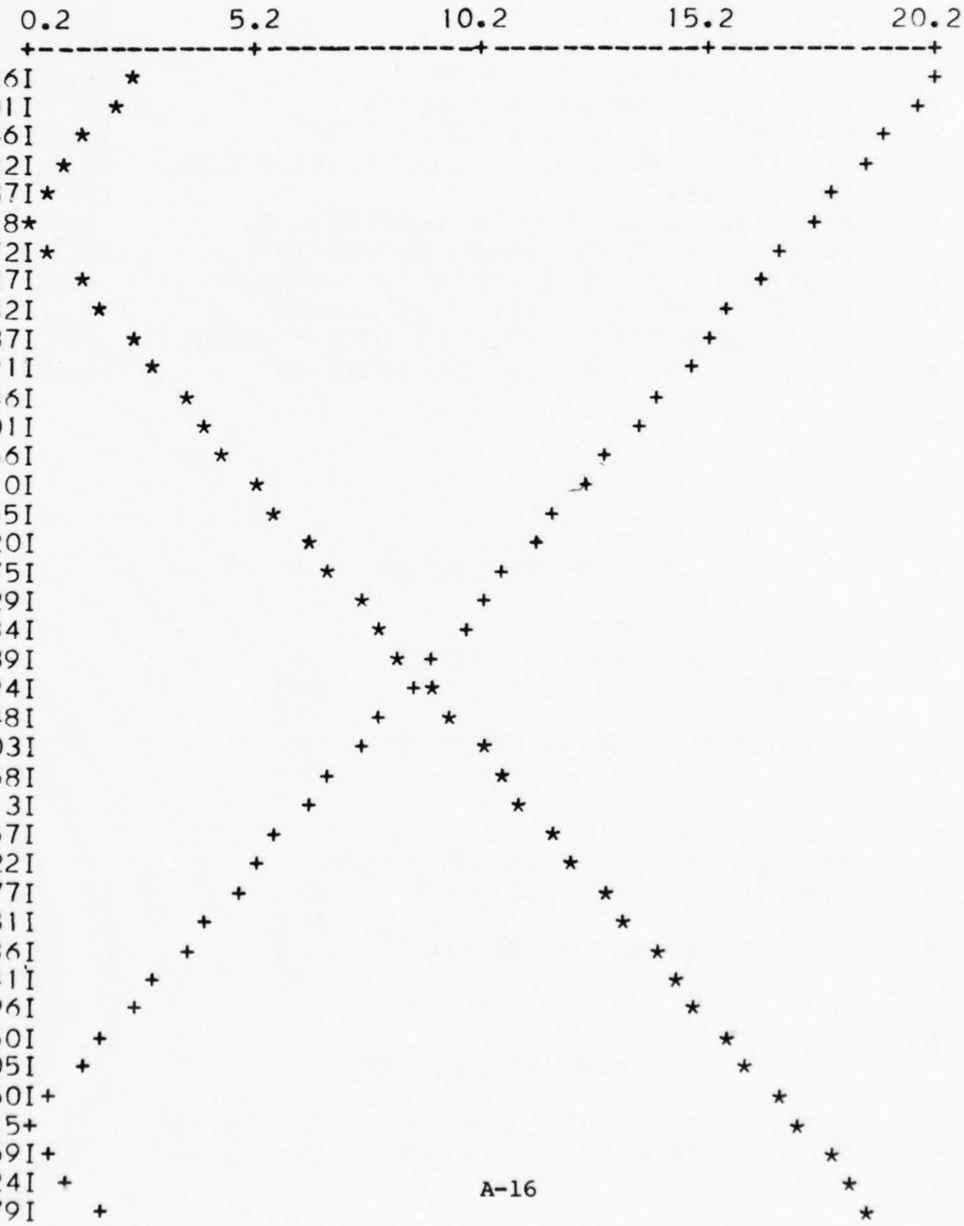


FIGURE A-13

PLOT OF DISPLACEMENT AT ITEM STATIONS
FOR HALF-MOUNT SPACING 63.0 INCHES
FOREWARD DROP=+ AFT DROP=*
(HIGH TEMPERATURE)

IS IN	FDS INS	ADS INS
0	3.55	0.32
5	3.47	0.39
10	3.39	0.47
15	3.31	0.55
19	3.23	0.63
24	3.15	0.71
29	3.07	0.79
34	2.99	0.87
39	2.91	0.94
44	2.83	1.02
49	2.75	1.10
54	2.67	1.18
58	2.59	1.26
63	2.51	1.34
68	2.43	1.42
73	2.35	1.49
78	2.27	1.57
83	2.19	1.65
88	2.11	1.73
93	2.03	1.81
97	1.95	1.89
102	1.87	1.96
107	1.79	2.04
112	1.71	2.12
117	1.63	2.20
122	1.55	2.28
127	1.47	2.36
132	1.39	2.44
136	1.31	2.51
141	1.23	2.59
146	1.15	2.67
151	1.07	2.75
156	0.99	2.83
161	0.91	2.91
166	0.83	2.99
171	0.75	3.06
175	0.67	3.14
180	0.59	3.22
185	0.52	3.30
190	0.44	3.38

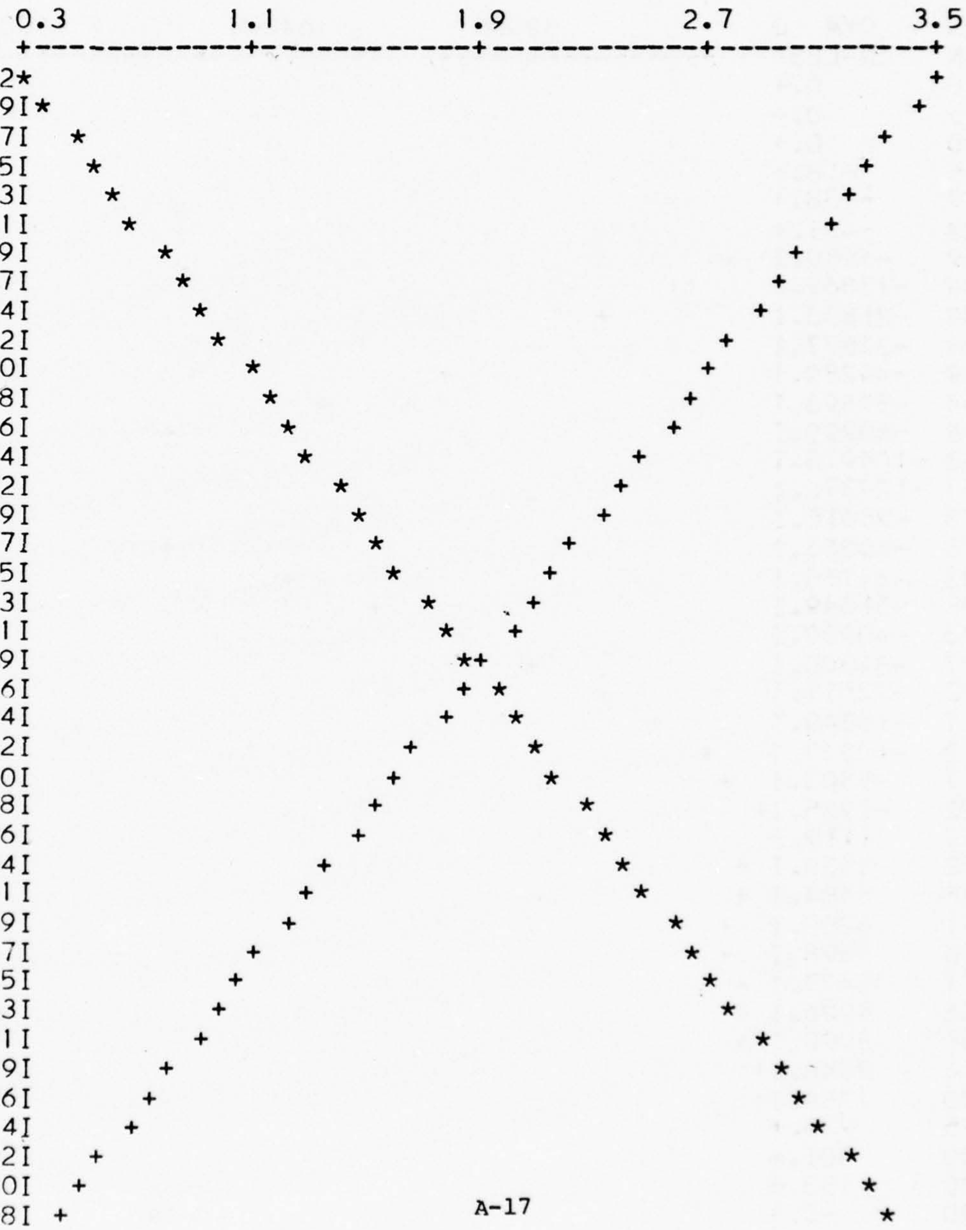


FIGURE A-14

DYNAMIC BENDING MOMENTS
ROTATIONAL EDGEWISE DROP
(FORWARD END 18.0 INCHES)

Scale: 0 32000 64000 96000 128000

IS IN	DYM IN-LBS
0	0.
5	0.
10	0.
15	-18.
19	-138.
24	-491.
29	-6950.
34	-13869.
39	-21833.
44	-32877.
49	-44289.
54	-59693.
58	-80990.
63	-106973.
67	-127376.
73	-98610.
78	-80263.
83	-64760.
88	-51649.
93	-40929.
97	-31300.
102	-22557.
107	-15840.
112	-10247.
117	-5803.
122	-1985.
127	1119.
132	3639.
136	5484.
141	6260.
146	5898.
151	5477.
156	4926.
161	3990.
166	2748.
170	1359.
175	930.
180	501.
185	153.
190	-0.

FIGURE A-15

DYNAMIC BENDING MOMENTS
ROTATIONAL EDGEWISE DROP
(AFT END 18.0 INCHES)

Scale (DYM, IN-LBS): 0, 17000, 34000, 51000, 68000

IS IN	DYM IN-LBS
0	0.
5	0.
10	0.
15	1.
19	7.
24	17.
29	-45.
34	-116.
39	-294.
44	-803.
49	-1375.
54	-2774.
58	-5622.
63	-9860.
67	-13634.
73	4852.
78	17277.
83	28138.
88	37499.
93	45144.
97	51923.
102	57869.
107	61683.
112	64155.
117	65083.
122	65022.
127	63710.
132	61220.
136	57056.
141	50020.
146	39262.
151	28278.
156	16586.
161	2463.
166	-14279.
170	-32754.
175	-17607.
180	-7984.
185	-2085.
190	0.

TABLE A-4

RESPONSE TO 25G, 25MS HALFSINE SHOCK SUMMARY TABLE

INPUT PARAMETERS

SUPPORT LOCATIONS(IS)	FWD	66.70	
	AFT	170.00	
LONGITUDINAL SHOCK FREQUENCY-	HIGH TEMPERATURE	6.10	HZ
	LOW TEMPERATURE	7.30	HZ
IMPACT VELOCITY		12.40	FPS
NUMBER OF LONGITUDINAL BEARING RESTAINTS		1	
LOCATION OF LONG BEARING RESTRAINTS(IS)		136.00	
ECCENTRICITIES		7.75	INS

RESULTS

DISPLACEMENT		3.89	INS
DECELERATION		17.66	G
DYNAMIC SUPPORT REACTIONS	FWD	2705.03	LBS
	AFT	-1339.95	LBS
DYNAMIC BENDING MOMENTS	FWD	-8030.66	IN-LBS
	AFT	-1816.03	IN-LBS

DYNAMIC BENDING MOMENTS AT LONGITUDINAL RESTRAINTS

1ST BEARING RESTRAINT	128979.66	-57856.79	IN-LBS

REMARKS

IMPACT VELOCITY EQUIVALENT NOT ACTUAL (SEE TEXT P.11)

FIGURE A-16
ITEM DYNAMIC MOMENTS
END IMPACT ANALYSIS
IMPACT VELOCITY 12.40 FEET PER SECOND

Scale: 0, 33000, 66000, 99000, 132000

IS IN	DYM IN-LBS
0	0.
5	0.
10	0.
15	-1.
19	-7.
24	-27.
29	-398.
34	-795.
39	-1258.
44	-1916.
49	-2598.
54	-3554.
58	-4930.
63	-6652.
68	-4617.
73	6207.
78	16780.
83	27101.
88	37199.
93	47062.
97	56813.
102	66465.
107	75879.
112	85152.
117	94269.
122	103295.
127	112207.
132	121018.
136	128979.
141	-48694.
146	-40525.
151	-32372.
156	-24268.
161	-16326.
166	-8553.
171	-2222.
175	-965.
180	-433.
185	-112.
190	-0.

FIGURE A-17
ITEM AXIAL LOADS
END IMPACT ANALYSIS
IMPACT VELOCITY 12.40 FEET PER SECOND

AXL 0 5000 10000 15000 20000

IS IN	AXL LBS
0	0.
5	1.
10	1.
15	11.
19	45.
24	649.
29	1428.
34	1457.
39	2345.
44	2407.
49	2800.
54	4237.
58	5619.
63	6840.
68	8003.
73	8987.
78	9898.
83	10776.
88	11588.
93	12287.
97	12578.
102	13209.
107	13897.
112	14472.
117	14866.
122	15291.
127	15679.
132	15981.
136	17051.
141	-6426.
146	-5913.
151	-5871.
156	-5429.
161	-4824.
166	-4016.
171	-3173.
175	-2342.
180	-1517.
185	-759.
190	-121.

TABLE A-5

RESPONSE TO 15G, 35MS TRAPEZOIDAL SHOCK SUMMARY TABLE

INPUT PARAMETERS

SUPPORT LOCATIONS (IS)	FWD	66.70
	AFT	170.00
VERTICAL SHOCK FREQ		6.40 HZ
DROP HEIGHT		21.30 INS
WEIGHT OF THE CONTAINER SHELL		600.00 LBS

RESULTS

PRIMARY-		
DISPLACEMENT		3.44 INS
DECELERATION		14.38 G
REBOUND-		
DISPLACEMENT		1.05 INS
DECELERATION		4.39 G
DYNAMIC SUPPORT REACTIONS	FWD	12892.35 LBS
	AFT	6741.71 LBS
DYNAMIC BENDING MOMENTS	FWD	-115505.65 IN-LBS
	AFT	-26120.09 IN-LBS

REMARKS

DROP HEIGHT EQUIVALENT NOT ACTUAL (SEE TEXT P.11)

FIGURE A-18
FLAT DROP ANALYSIS
PLOT OF DYNAMIC BENDING MOMENTS VERSUS ITEM STATIONS
DYNAMIC BENDING MOMENTS(DYM)= +

DYM scale (IN-LBS): 0, 29000, 58000, 87000, 116000

IS IN	DYM IN-LBS
0	0.
5	0.
10	0.
15	-14.
19	-107.
24	-387.
29	-5721.
34	-11439.
39	-18100.
44	-27555.
49	-37364.
54	-51124.
58	-70908.
63	-95681.
66.7	-115505.
73	-76610.
78	-51275.
83	-29567.
88	-11062.
93	4061.
97	17572.
102	29665.
107	38330.
112	44958.
117	49364.
122	52436.
127	53884.
132	53875.
136	51921.
141	46707.
146	37466.
151	27990.
156	17818.
161	5311.
166	-9624.
170	-26120.
175	-13878.
180	-6228.
185	-1609.
190	-0.

TABLE A-6

RESPONSE TO 9G, 35MS TRAPEZOIDAL SHOCK SUMMARY TABLE

INPUT PARAMETERS

SUPPORT LOCATIONS(IS)	FWD	66.70
	AFT	170.00
TRANSVERSE SHOCK FREQUENCY-HIGH TEMPERATURE		17.30 HZ
	LOW TEMPERATURE	17.30 HZ
IMPACT VELOCITY		4.97 FPS

RESULTS

DISPLACEMENT		0.55 INS
DECELERATION		16.77 G
DYNAMIC SUPPORT REACTIONS	FWD	15036.26 LBS
	AFT	7862.81 LBS
DYNAMIC BENDING MOMENTS	FWD	-134713.45 IN-LBS
	AFT	-30463.69 IN-LBS

REMARKS IMPACT VELOCITY EQUIVALENT NOT ACTUAL (SEE TEXT P.11)

FIGURE A-19

SIDE IMPACT ANALYSIS

PLOT OF DYNAMIC BENDING MOMENTS VERSUS ITEM STATIONS

DYNAMIC BENDING MOMENTS(DYM)= +

DYM axis: 0, 34000, 68000, 102000, 136000

IS IN	DYM IN-LBS
0	0.
5	0.
10	0.
15	-16.
19	-125.
24	-452.
29	-6672.
34	-13341.
39	-21110.
44	-32137.
49	-43577.
54	-59625.
58	-82700.
63	-111592.
66.7	-134713.
73	-89350.
78	-59802.
83	-34484.
88	-12901.
93	4736.
97	20494.
102	34599.
107	44704.
112	52434.
117	57573.
122	61156.
127	62844.
132	62834.
136	60556.
141	54474.
146	43696.
151	32645.
156	20781.
161	6194.
166	-11224.
170	-30463.
175	-16186.
180	-7264.
185	-1876.
190	-0.

TABLE A-7

RESPONSE TO 6G, 35MS TRAPEZOIDAL SHOCK- SUMMARY TABLE
HARPOON MISSILE ASROC VERSION- SOLUTION 1

INPUT PARAMETERS

PULSE TYPE
TRAPEZIOD

PULSE PEAK	6.00	G-S
RISE TIME	0.00	MS
DWELL TIME	15.00	MS
DECAY TIME	10.00	MS
DAMPING FACTOR	0.00	

SUPPORT LOCATIONS(IS)	FWD	66.70	
	AFT	170.00	
LONGITUDINAL SHOCK FREQUENCY		6.40	HZ
NUMBER OF LONGITUDINAL BEARING RESTAINTS		1	
LOCATION OF LONG BEARING RESTRAINTS(IS)		136.00	
ECCENTRICITIES		7.75	INS

RESULTS

DISPLACEMENT		**1.36**	**INS**
DECELERATION		5.73	G
IMPACT VELOCITY		4.59	FPS
DYNAMIC SUPPORT REACTIONS	FWD	1483.58	LBS
	AFT	-118.50	LBS
DYN BENDING MOM AT SUPPORTS-	FWD	-8030.66	IN-LBS
	AFT	-1816.03	IN-LBS

DYNAMIC BENDING MOMENTS AT LONGITUDINAL RESTRAINTS

1ST BEARING RESTRAINT	44332.92	-16327.37	IN-LBS

AXIAL LOAD RESULTS

DYNAMIC AXIAL LOADS AT LONGITUDINAL RESTRAINTS

1ST BEARING RESTRAINT	5536.13	-2291.01	LBS

REMARKS

IMPACT VELOCITY EQUIVALENT NOT ACTUAL (SEE TEXT P.11)

FIGURE A-20

DYNAMIC BENDING MOMENTS
LONGITUDINAL SHOCK ANALYSIS
IMPACT VELOCITY 4.59 FEET PER SECOND

IS IN	MOM IN-LBS
0	0.
5	0.
10	0.
15	-1.
19	-7.
24	-27.
29	-398.
34	-795.
39	-1258.
44	-1916.
49	-2598.
54	-3554.
58	-4930.
63	-6652.
67	-8031.
73	-1582.
78	3041.
83	7411.
88	11558.
93	15470.
97	19271.
102	22972.
107	26435.
112	29757.
117	32924.
122	35999.
127	33960.
132	41820.
136	44333.
141	-13617.
146	-11398.
151	-9196.
156	-7043.
161	-5051.
166	-3229.
170	-1816.
175	-965.
180	-433.
185	-112.
190	0.

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FIGURE A-21

DYNAMIC AXIAL LOADS
LONGITUDINAL SHOCK ANALYSIS
IMPACT VELOCITY 4.59 FEET PER SECOND

IS IN	AXL LBS
0	0.
5	0.
10	0.
15	4.
19	14.
24	211.
29	464.
34	473.
39	761.
44	781.
49	909.
54	1376.
58	1824.
63	2221.
68	2598.
73	2918.
78	3214.
83	3499.
88	3762.
93	3989.
97	4084.
102	4288.
107	4512.
112	4699.
117	4827.
122	4965.
127	5091.
132	5188.
136	5536.
141	-2086.
146	-1920.
151	-1906.
156	-1763.
161	-1566.
166	-1304.
171	-1030.
175	-760.
180	-493.
185	-247.
190	-39.

Plot scale: 0, 2000, 4000, 6000, 8000

APPENDIX B

GLOSSARY OF TERMS USED
IN COMPUTER PRINTOUTS

ADC	DECELERATION- AFT EDGE DROP	G'S
ADS	DISPLACEMENT- AFT EDGE DROP	INCHES
AXL	AXIAL LOAD	POUNDS
DYM	DYNAMIC BENDING MOMENT	INCH-POUNDS
F	FREQUENCY	HERTZ
FDC	DECELERATION- FORWARD EDGE DROP	G'S
FDS	DISPLACEMENT- FORWARD EDGE DROP	INCHES
FR	FRAGILITY	G'S
FREQ	FREQUENCY	HERTZ
IR	ITEM RESPONSE TO FREQUENCY	G'S
IS	ITEM STATION	INCHES
RESP	RESPONSE SHOCK SPECTRUM	G'S
SPAC	HALF MOUNT SPACING	INCHES
SPEC	SPECIFICATION SHOCK SPECTRUM	G'S

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FIGURE B-1

TRANSVERSE ANALYSIS
PLOT OF FRAGILITY AND ITEM RESPONSE VERSUS FREQUENCY
FRAGILITY(FR) = +
ITEM RESPONSE(IR) = *

F HZ	FR G	IR G
5.0	5.00	1.40
6.0	5.00	1.39
7.0	5.00	1.44
8.0	5.00	1.52
9.0	5.00	1.15
10.0	5.00	0.89
11.0	5.00	0.96
12.0	5.00	1.06
13.0	5.00	1.21
14.0	5.00	1.44
15.0	5.00	1.67
16.0	5.00	2.02
17.0	5.00	2.41
18.0	5.00	2.78
19.0	5.00	2.86
20.0	3.00	2.82
21.0	3.00	2.52
22.0	3.00	2.18
23.0	3.00	1.96
24.0	3.00	1.78
25.0	2.00	1.64
26.0	2.00	0.79
27.0	2.00	0.74
28.0	2.00	0.69
29.0	2.00	0.66
30.0	2.00	0.63
31.0	2.00	0.60
32.0	2.00	0.60
33.0	2.00	0.58
34.0	2.00	0.38
35.0	2.00	0.35
36.0	2.00	0.33
37.0	2.00	0.31
38.0	2.00	0.30
39.0	2.00	0.28
40.0	2.00	0.26
50.0	2.00	0.20
60.0	2.00	0.20
70.0	2.00	0.18
80.0	2.00	0.16
90.0	2.00	0.15
100.0	0.25	0.14
150.0	0.25	0.13
200.0	0.25	0.11
250.0	2.00	0.09
300.0	2.00	0.07
350.0	2.00	0.07
400.0	2.00	0.06
500.0	2.00	0.03

FIGURE B-2

VERTICAL ANALYSIS

PLOT OF FRAGILITY AND ITEM RESPONSE VERSUS FREQUENCY

FRAGILITY(FR) = +

ITEM RESPONSE(IR) = *

```
     F     FR    IR 0.0                                              5.0
    HZ      G      G +-------------------------------------------------+
   5.0   5.00   2.32 I                      *                          +
   6.0   5.00   1.92 I                  *                              +
   7.0   5.00   2.35 I                      *                          +
   8.0   5.00   3.07 I                              *                  +
   9.0   5.00   4.26 I                                          *      +
  10.0   5.00   4.97 I                                                 $
  11.0   5.00   3.66 I                                    *            +
  12.0   5.00   2.43 I                        *                        +
  13.0   5.00   1.24 I           *                                     +
  14.0   5.00   0.73 I      *                                          +
  15.0   5.00   0.57 I     *                                           +
  16.0   5.00   0.48 I    *                                            +
  17.0   5.00   0.41 I   *                                             +
  18.0   5.00   0.35 I  *                                              +
  19.0   5.00   0.30 I  *                                              +
  20.0   3.00   0.30 I  *                          +
  21.0   3.00   0.29 I  *                          +
  22.0   3.00   0.28 I  *                          +
  23.0   3.00   0.28 I  *                          +
  24.0   3.00   0.28 I  *                          +
  25.0   2.00   0.28 I  *                +
  26.0   2.00   0.15 I*                  +
  27.0   2.00   0.14 I*                  +
  28.0   2.00   0.14 I*                  +
  29.0   2.00   0.14 I*                  +
  30.0   2.00   0.14 I*                  +
  31.0   2.00   0.14 I*                  +
  32.0   2.00   0.14 I*                  +
  33.0   2.00   0.15 I*                  +
  34.0   2.00   0.10 I*                  +
  35.0   2.00   0.09 I*                  +
  36.0   2.00   0.09 I*                  +
  37.0   2.00   0.09 I*                  +
  38.0   2.00   0.08 I*                  +
  39.0   2.00   0.08 I*                  +
  40.0   2.00   0.08 I*                  +
  50.0   2.00   0.07 I*                  +
  60.0   2.00   0.07 I*                  +
  70.0   2.00   0.07 I*                  +
  80.0   2.00   0.07 I*                  +
  90.0   2.00   0.06 I*                  +
 100.0   0.25   0.06 I*+
 150.0   0.25   0.06 I*+
 200.0   0.25   0.05 I*+
 250.0   2.00   0.05 *                   +
 300.0   2.00   0.04 *                   +
 350.0   2.00   0.04 *                   +
 400.0   2.00   0.03 *                   +
 500.0   2.00   0.02 *                   +
```

FIGURE B-3

LONGITUDINAL ANALYSIS
PLOT OF FRAGILITY AND ITEM RESPONSE VERSUS FREQUENCY
FRAGILITY(FR) = +
ITEM RESPONSE(IR) = *

F HZ	FR G	IR G
5.0	2.00	0.15
6.0	2.00	0.25
7.0	2.00	0.43
8.0	2.00	0.74
9.0	2.00	1.12
10.0	2.00	1.43
11.0	2.00	1.11
12.0	2.00	0.87
13.0	2.00	0.76
14.0	2.00	0.62
15.0	2.00	0.57
16.0	2.00	0.35
17.0	2.00	0.33
18.0	2.00	0.31
19.0	2.00	0.30
20.0	2.00	0.30
21.0	2.00	0.29
22.0	2.00	0.28
23.0	2.00	0.27
24.0	2.00	0.28
25.0	2.00	0.28
26.0	2.00	0.15
27.0	2.00	0.14
28.0	2.00	0.14
29.0	2.00	0.14
30.0	2.00	0.14
31.0	2.00	0.14
32.0	2.00	0.14
33.0	2.00	0.15
34.0	2.00	0.08
35.0	2.00	0.08
36.0	2.00	0.08
37.0	2.00	0.08
38.0	2.00	0.08
39.0	2.00	0.08
40.0	2.00	0.08
50.0	2.00	0.07
60.0	2.00	0.07
70.0	2.00	0.07
80.0	2.00	0.07
90.0	2.00	0.06
100.0	0.25	0.06
150.0	0.25	0.06
200.0	0.25	0.05
250.0	2.00	0.05
300.0	2.00	0.04
350.0	2.00	0.04
400.0	2.00	0.03
500.0	2.00	0.02

FIGURE B-4

COMPARISON OF 42G, 25MS TPS (SPECIFICATION) TO 20.8G, 48MS HALFSINE
FROM -20^{o}F FORWARD EDGE DROP (RESPONSE)

SHOCK SPECTRUM
SPECIFICATION = *
RESPONSE = +

FREQ HZ	SPEC G	RESP G
2.	6.5	8.0
4.	12.8	15.5
6.	19.0	22.3
8.	24.9	27.9
10.	30.3	32.1
14.	39.7	36.3
18.	46.7	36.9
22.	51.0	35.8
26.	52.5	33.9
30.	51.8	32.0
34.	48.4	29.9
38.	44.2	28.1
42.	40.0	26.4
46.	37.3	24.8
50.	36.7	23.3
60.	42.0	24.2
70.	45.8	24.5
80.	42.0	23.8
90.	39.0	22.8
100.	42.0	22.8
110.	44.4	23.0
120.	42.0	22.8
130.	39.9	22.3
140.	42.0	22.1
150.	43.7	22.4

FIGURE B-5

COMPARISON OF 42G, 25MS TPS (SPECIFICATION) TO RESPONSE TO 9G, 35MS TRAPEZOIDAL SHOCK (RESPONSE)

SHOCK SPECTRUM
SPECIFICATION = *
RESPONSE = +

FREQ HZ	SPEC G	RESP G
2.	6.5	4.7
4.	12.8	9.3
6.	19.0	13.6
8.	24.9	17.5
10.	30.3	20.8
14.	39.7	25.4
18.	46.7	27.3
22.	51.0	27.3
26.	52.5	26.1
30.	51.8	24.5
34.	48.4	22.9
38.	44.2	21.3
42.	40.0	19.9
46.	37.3	18.7
50.	36.7	17.9
60.	42.0	17.8
70.	45.8	17.8
80.	42.0	17.5
90.	39.0	17.3
100.	42.0	17.3
110.	44.4	17.1
120.	42.0	17.1
130.	39.9	17.1
140.	42.0	17.0
150.	43.7	16.9

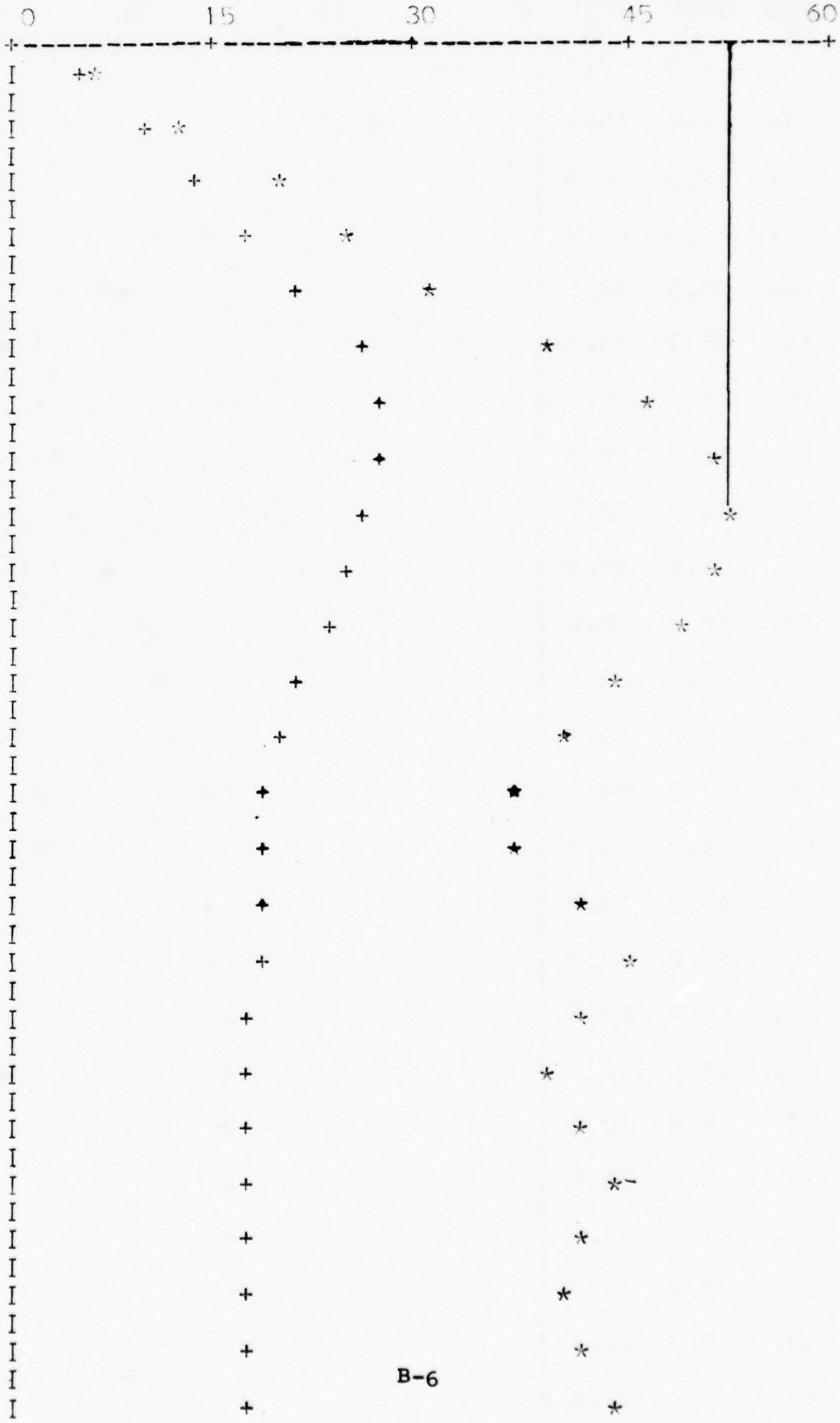

FIGURE B-6

COMPARISON OF 42G, 25MS TPS (SPECIFICATION) TO RESPONSE TO 25G, 25MS HALFSINE SHOCK (RESPONSE)

SHOCK SPECTRUM
SPECIFICATION = *
RESPONSE = +

FREQ HZ	SPEC G	RESP G
2.	6.5	9.6
4.	12.8	18.6
6.	19.0	26.5
8.	24.9	33.0
10.	30.3	37.6
14.	39.7	41.5
18.	46.7	41.1
22.	51.0	39.0
26.	52.5	36.2
30.	51.8	33.4
34.	48.4	30.8
38.	44.2	28.6
42.	40.0	26.8
46.	37.3	25.4
50.	36.7	24.8
60.	42.0	25.1
70.	45.8	24.7
80.	42.0	24.7
90.	39.0	24.8
100.	42.0	24.6
110.	44.4	24.6
120.	42.0	24.6
130.	39.9	24.5
140.	42.0	24.5
150.	43.7	24.4

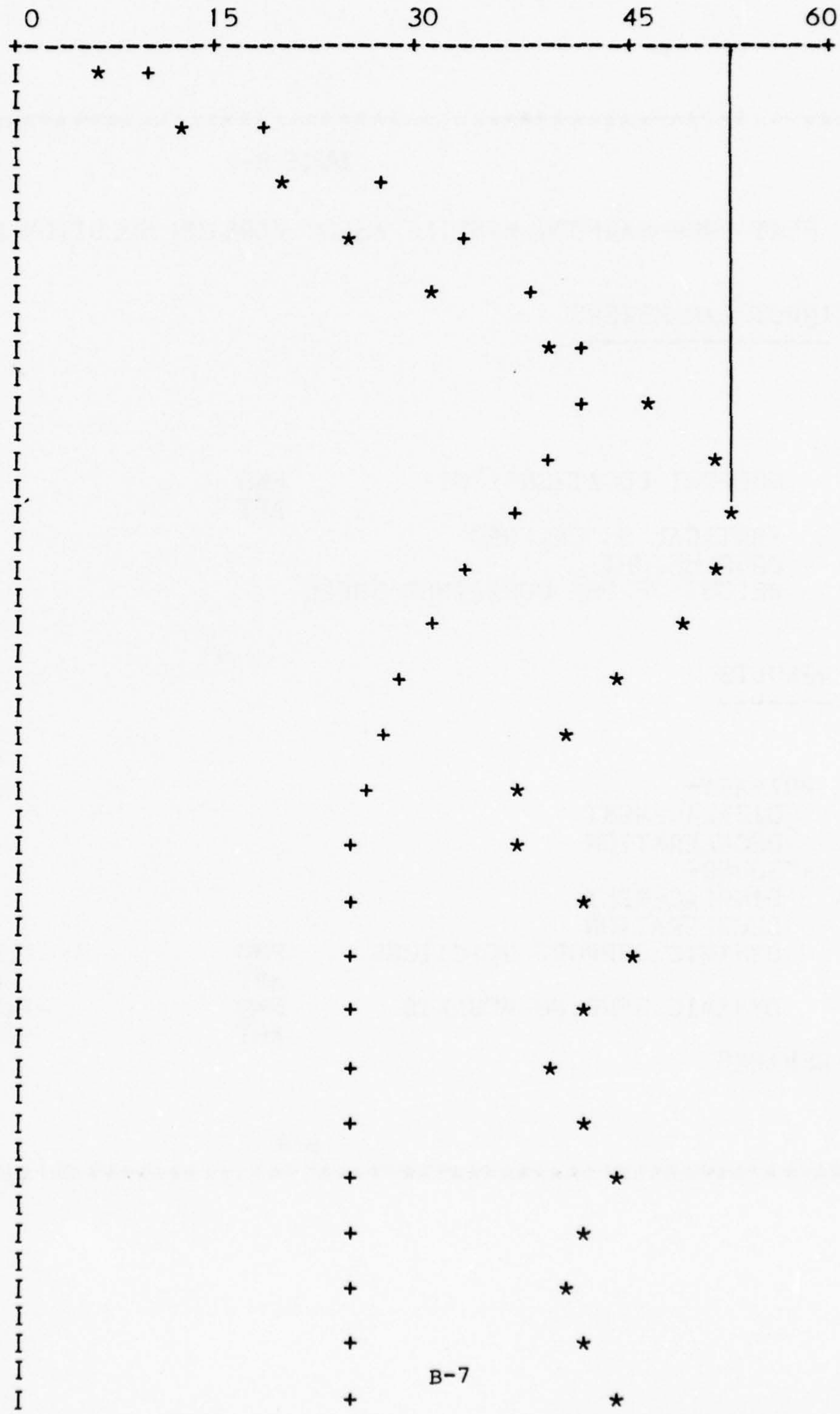

TABLE B-1

FLAT DROP-HARPOON MISSILE ASROC VERSION SOLUTION 2

INPUT PARAMETERS

SUPPORT LOCATIONS(IS)	FWD	66.70
	AFT	170.00
VERTICAL SHOCK FREQ		9.10 HZ
DROP HEIGHT		18.00 INS
WEIGHT OF THE CONTAINER SHELL		600.00 LBS

RESULTS

PRIMARY-		
DISPLACEMENT		2.19 INS
DECELERATION		18.47 G
REBOUND-		
DISPLACEMENT		0.67 INS
DECELERATION		5.64 G
DYNAMIC SUPPORT REACTIONS	FWD	16558.12 LBS
	AFT	8658.63 LBS
DYNAMIC BENDING MOMENTS	FWD	-148348.20 IN-LBS
	AFT	-33547.00 IN-LBS

REMARKS

FIGURE B-7
FLAT DROP ANALYSIS
PLOT OF DYNAMIC BENDING MOMENTS VERSUS ITEM STATIONS
DYNAMIC BENDING MOMENTS(DYM)= +

Scale: 0 — 38000 — 76000 — 114000' — 152000

IS IN	DYM IN-LBS
0	0.
5	0.
10	0.
15	-18.
19	-137.
24	-497.
29	-7348.
34	-14692.
39	-23246.
44	-35390.
49	-47987.
54	-65660.
58	-91070.
63	-122887.
66.7	-148348.
73	-98393.
78	-65855.
83	-37974.
88	-14207.
93	5215.
97	22568.
102	38100.
107	49228.
112	57741.
117	63400.
122	67346.
127	69205.
132	69193.
136	66685.
141	59987.
146	48119.
151	35949.
156	22885.
161	6821.
166	-12360.
170	-33547
175	-17824.
180	-7999.
185	-2066.
190	-0.

TABLE B-2

END IMPACT-HARPOON MISSILE ASROC VERSION SOLUTION 2

INPUT PARAMETERS

SUPPORT LOCATIONS(IS)	FWD	66.70	
	AFT	170.00	
LONGITUDINAL SHOCK FREQUENCY-	HIGH TEMPERATURE	8.60	HZ
	LOW TEMPERATURE	10.40	HZ
IMPACT VELOCITY		10.00	FPS
LOCATION OF LONG FRICTION RESTRAINTS(IS)		66.70	
		170.00	
MAGNITUDES OF THE FRICTION FORCES		9000.00	LBS
		9000.00	LBS
NUMBER OF LONGITUDINAL BEARING RESTAINTS		1	
LOCATION OF LONG BEARING RESTRAINTS(IS)		136.00	
ECCENTRICITIES		7.75	INS

RESULTS

DISPLACEMENT		2.22	INS
DECELERATION		20.29	G
DYNAMIC SUPPORT REACTIONS	FWD	1623.94	LBS
	AFT	-258.86	LBS
DYNAMIC BENDING MOMENTS	FWD	-8030.66	IN-LBS
	AFT	-1816.03	IN-LBS

DYNAMIC BENDING MOMENTS AT LONGITUDINAL RESTRAINTS

1ST BEARING RESTRAINT	54059.98	-21099.66	IN-LBS

REMARKS

FIGURE B-8
ITEM DYNAMIC MOMENTS
END IMPACT ANALYSIS
IMPACT VELOCITY 10.00 FEET PER SECOND

DYM scale: 0 — 14000 — 28000 — 42000 — 56000

IS IN	DYM IN-LBS
0	0.
5	0.
10	0.
15	-1.
19	-7.
24	-27.
29	-398.
34	-795.
39	-1258.
44	-1916.
49	-2598.
54	-3554.
58	-4930.
63	-6652.
68	-6246.
73	-687.
78	4619.
83	9673.
88	14505.
93	19101.
97	23585.
102	27970.
107	32117.
112	36123.
117	39974.
122	43732.
127	47377.
132	50921.
136	54059.
141	-17647.
146	-14745.
151	-11859.
156	-9022.
161	-6347.
166	-3841.
171	-1822.
175	-965.
180	-433.
185	-112.
190	-0.

FIGURE B-9
ITEM AXIAL LOADS
END IMPACT ANALYSIS
IMPACT VELOCITY 10.00 FEET PER SECOND

AXL (LBS): 0 3000 6000 9000 12000

IS IN	AXL LBS
0	0.
5	1.
10	2.
15	13.
19	51.
24	746.
29	1641.
34	1674.
39	2694.
44	2765.
49	3217.
54	4868.
58	6455.
63	7859.
66.7	8914.
73	1325.
78	2372.
83	3381.
88	4314.
93	5116.
97	5451.
102	6175.
107	6966.
112	7627.
117	8080.
122	8568.
127	9014.
132	9361.
136	10590.
141	1617.
146	2206.
151	2255.
156	2762.
161	3458.
166	4386.
171	3934.
175	-2690.
180	-1743.
185	-872.
190	-139.

FIGURE B-10

PLOT OF DECELERATION VS.
HALF-MOUNTSPACING
FOREWARD DROP=+ AFT DROP=*
(LOW TEMPERATURE)

SPAC IN	FDC G	ADC G
10	14.51	14.93
12	15.02	15.41
14	15.54	15.89
16	16.05	16.37
19	16.56	16.85
21	17.08	17.33
23	17.59	17.80
25	18.10	18.28
27	18.61	18.76
29	19.13	19.24
31	19.64	19.72
33	20.15	20.20
36	20.67	20.68
38	21.18	21.16
40	21.69	21.64
42	22.20	22.12
44	22.72	22.59
46	23.23	23.07
48	23.74	23.55
50	24.26	24.03
53	24.77	24.51
55	25.28	24.99
57	25.80	25.47
59	26.31	25.95
61	26.82	26.43
63	27.33	26.90
65	27.85	27.38
67	28.36	27.86
70	28.87	28.34
72	29.39	28.82
74	29.90	29.30
76	30.41	29.78
78	30.92	30.26
80	31.44	30.74
82	31.95	31.21
84	32.46	31.69
87	32.98	32.17
89	33.49	32.65
91	34.00	33.13
93	34.52	33.61

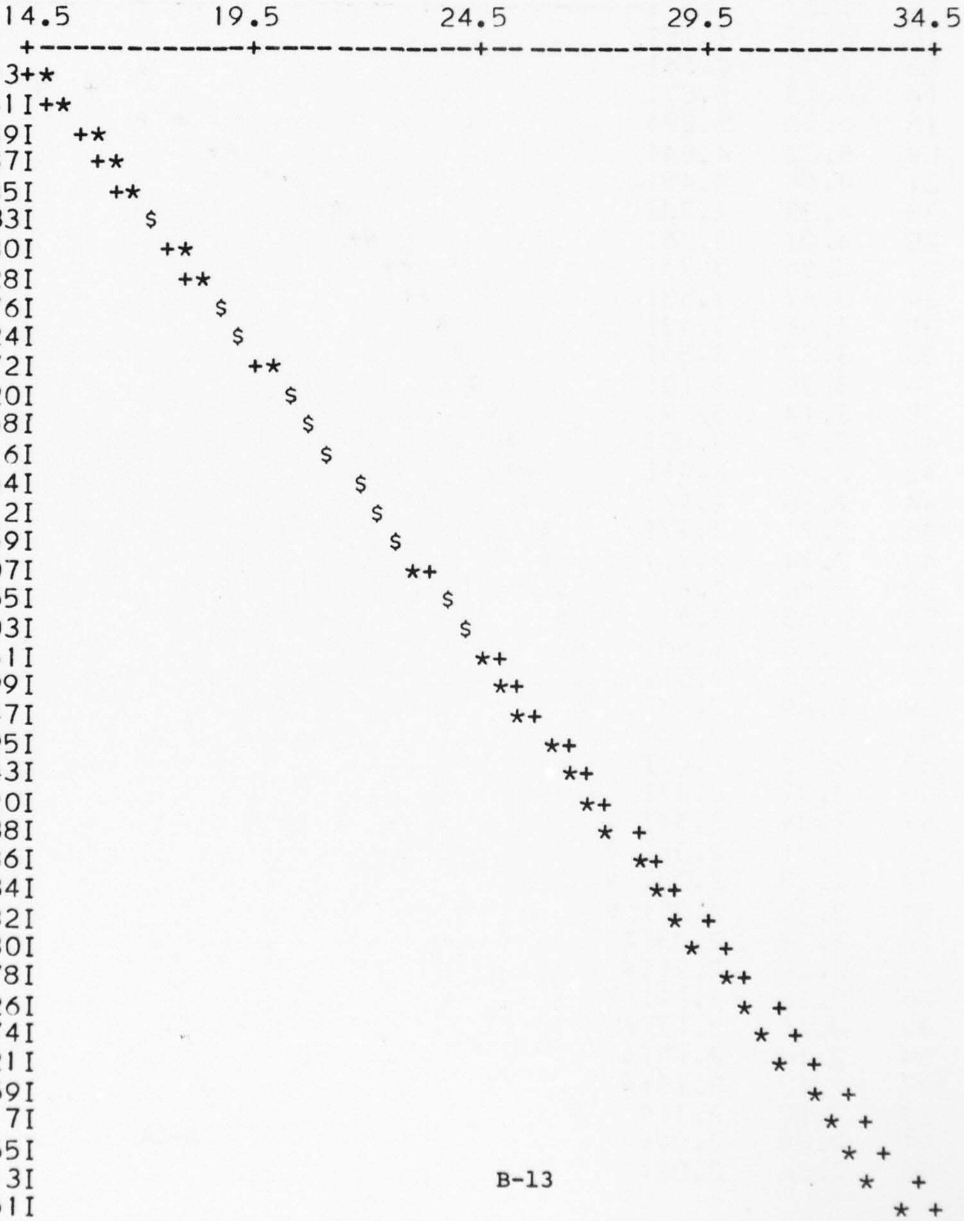

FIGURE B-11

PLOT OF DISPLACEMENT VS
HALF-MOUNT SPACING
FOREWARD DROP=+ AFT DROP=*
(HIGH TEMPERATURE)

SPAC IN	FDS INS	ADS INS
10	8.17	7.78
12	6.97	6.66
14	6.13	5.87
16	5.50	5.29
19	5.02	4.84
21	4.64	4.49
23	4.33	4.20
25	4.07	3.96
27	3.86	3.75
29	3.67	3.58
31	3.51	3.43
33	3.37	3.30
36	3.25	3.19
38	3.14	3.09
40	3.05	3.00
42	2.96	2.91
44	2.88	2.84
46	2.81	2.77
48	2.74	2.71
50	r.68	2.66
53	2.63	2.61
55	2.58	2.56
57	2.53	2.51
59	2.49	2.47
61	2.45	2.44
63	2.41	2.40
65	2.37	2.37
67	2.34	2.34
70	2.31	2.31
72	2.28	2.28
74	2.25	2.25
76	2.23	2.23
78	2.20	2.21
80	2.18	2.19
82	2.16	2.17
84	2.14	2.15
87	2.12	2.13
89	2.10	2.11
91	2.08	2.09
93	2.06	2.08

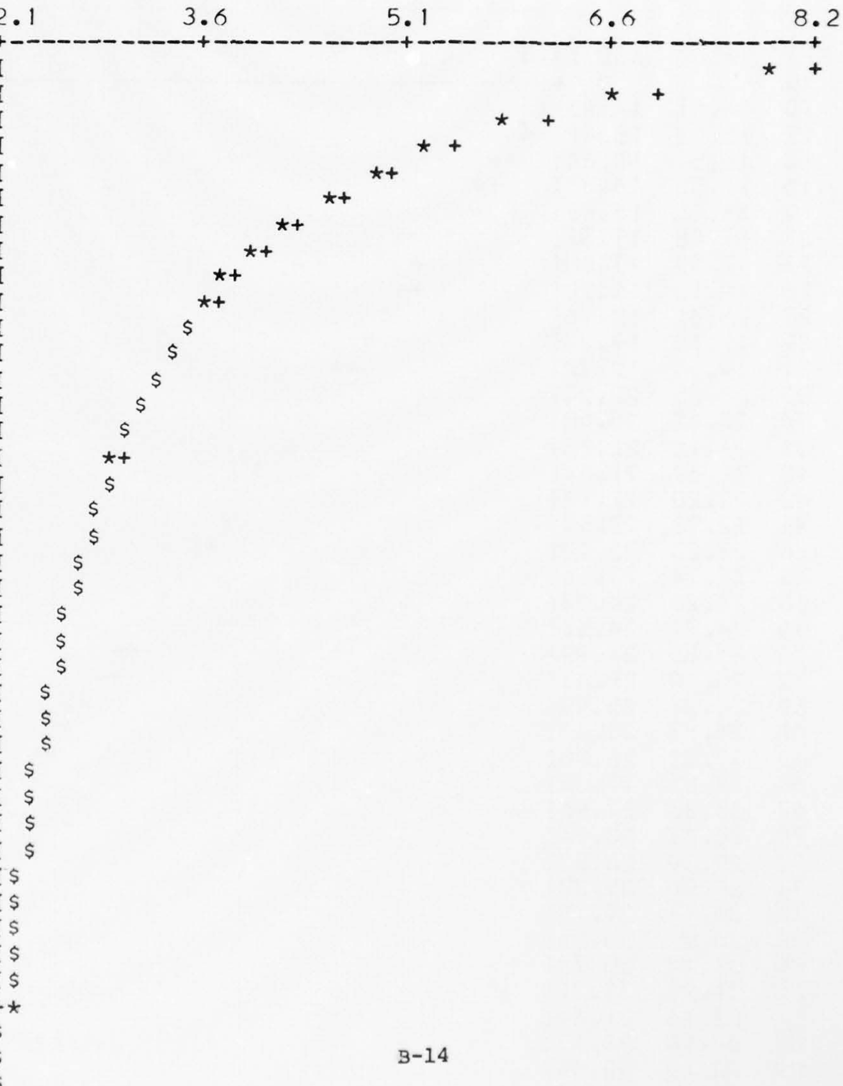

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TABLE B-3

ROTATIONAL EDGEWISE DROP
HARPOON MISSILE ASROC VERSION

INPUT PARAMETERS

HALF MOUNT SPACING		36.00	INS
SUPPORT LOCATIONS(IS)	FWD	66.70	
	AFT	170.00	
OVERALL CONTAINER LENGTH		185.77	INS
ITEM PITCH MOMENT OF INERTIA		9168.00	IN-LB-SECSQ
DISTANCE ITEM C.G. TO CONT BASE		16.00	INS
DISTANCE ITEM C.G. TO CONT FORWARD END		95.91	INS
DROP HEIGHT		18.00	INS
VERTICAL FREQUENCY-LOW TEMPERATURE		10.40	HZ
VERTICAL FREQUENCY-HIGH TEMPERATURE		8.60	HZ
LOCATION FOR DEC CALCULATIONS-FORWARD		9.63	(IS)
LOCATION FOR DEC CALCULATIONS-AFT		190.00	(IS)
LOCATION FOR DSPL CALCULATIONS-FORWARD		9.63	(IS)
LOCATION FOR DSPL CALCULATIONS-AFT		190.00	(IS)

RESULTS

AT LOW TEMPERATURE

FORWARD EDGE DROP

MAXIMUM DECELERATION AT(IS)	9.63	20.79	G
DYNAMIC SUPPORT REACTIONS	FWD	13901.38	LBS
	AFT	2612.37	LBS
DYN BENDING MOM AT SUPPORTS-	FWD	-145615.57	IN-LBS
	AFT	-8135.19	IN-LBS

AFT EDGE DROP

MAXIMUM DECELERATION AT(IS)	190.00	20.79	G
DYNAMIC SUPPORT REACTIONS	FWD	8355.77	LBS
	AFT	8950.71	LBS
DYN BENDING MOM AT SUPPORTS-	FWD	-54134.01	IN-LBS
	AFT	-36632.53	IN-LBS

AT HIGH TEMPERATURE

FWD EDGE DROP DISPLACEMENT AT(IS) 3.23
AFT EDGE DROP DISPLACEMENT AT(IS) 3.16

FIGURE B-12

PLOT OF DECELERATION AT ITEM STATIONS
FOR HALF-MOUNT SPACING 36.0 INCHES
FOREWARD DROP=+ AFT DROP=*
(LOW TEMPERATURE)

IS IN	FDC G	ADC G
0	21.69	3.24
5	21.23	3.69
10	20.78	4.14
15	20.32	4.59
19	19.86	5.04
24	19.40	5.49
29	18.95	5.94
34	18.49	6.39
39	18.03	6.84
44	17.57	7.29
49	17.12	7.74
54	16.66	8.19
58	16.20	8.64
63	15.74	9.09
68	15.29	9.54
73	14.83	9.99
78	14.37	10.44
83	13.91	10.89
88	13.46	11.34
93	13.00	11.79
97	12.54	12.24
102	12.08	12.69
107	11.63	13.14
112	11.17	13.59
117	10.71	14.04
122	10.25	14.49
127	9.80	14.94
132	9.34	15.39
136	8.88	15.84
141	8.42	16.29
146	7.97	16.74
151	7.51	17.19
156	7.05	17.64
161	6.60	18.09
166	6.14	18.54
171	5.68	18.99
175	5.22	19.44
180	4.77	19.89
185	4.31	20.34
190	3.85	20.79

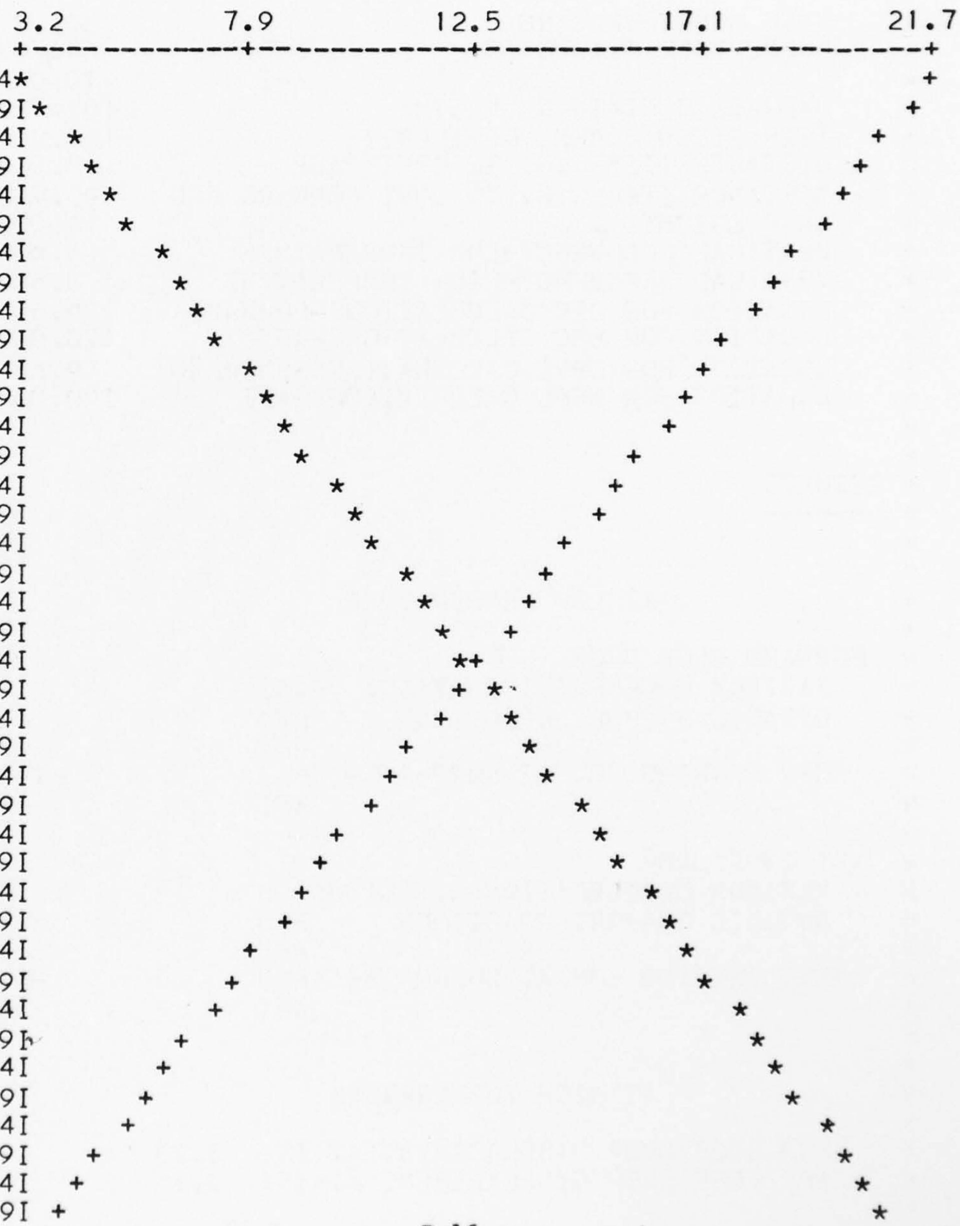

FIGURE B-13

PLOT OF DISPLACEMENT AT ITEM STATIONS
FOR HALF-MOUNT SPACING 36.0 INCHES
FOREWARD DROP=+ AFT DROP=*
(HIGH TEMPERATURE)

IS IN	FDS INS	ADS INS
0	3.42	-0.68
5	3.32	-0.58
10	3.22	-0.48
15	3.12	-0.38
19	3.02	-0.28
24	2.92	-0.18
29	2.82	-0.08
34	2.72	0.01
39	2.62	0.11
44	2.52	0.21
49	2.42	0.31
54	2.32	0.41
58	2.22	0.51
63	2.12	0.60
68	2.02	0.70
73	1.92	0.80
78	1.82	0.90
83	1.72	1.00
88	1.62	1.10
93	1.52	1.19
97	1.42	1.29
102	1.32	1.39
107	1.22	1.49
112	1.12	1.59
117	1.02	1.69
122	0.92	1.79
127	0.82	1.89
132	0.72	1.98
136	0.62	2.08
141	0.52	2.18
146	0.42	2.28
151	0.32	2.38
156	0.22	2.47
161	0.12	2.57
166	0.02	2.67
171	-0.08	2.77
175	-0.18	2.87
180	-0.28	2.97
185	-0.38	3.06
190	-0.48	3.16

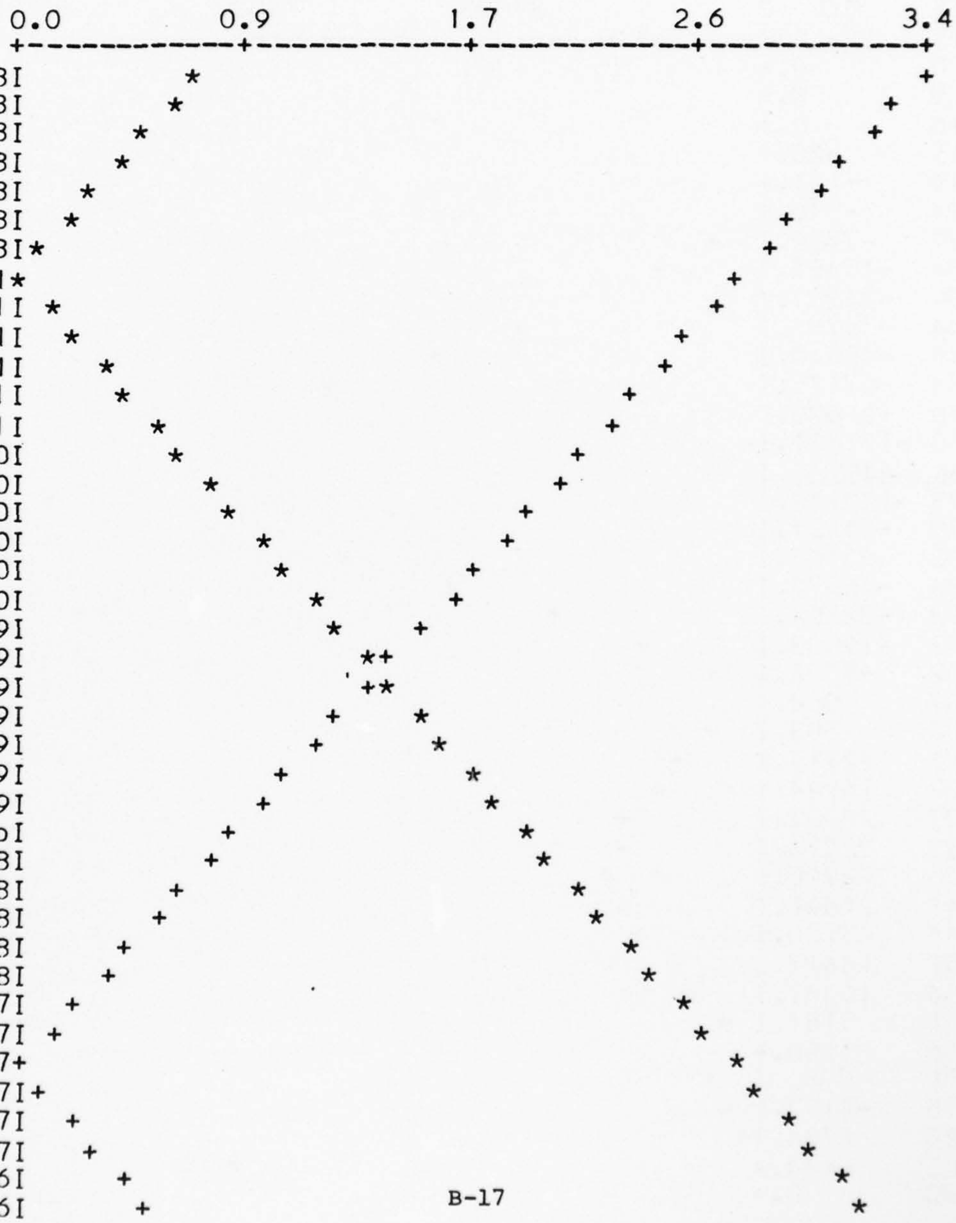

FIGURE B-14

DYNAMIC BENDING MOMENTS
ROTATIONAL EDGEWISE DROP
(FORWARD END 18.0 INCHES)

Plot scale (IN-LBS): 0, 37000, 74000, 111000, 148000

IS IN	DYM IN-LBS
0	0.
5	0.
10	0.
15	-20.
19	-151.
24	-540.
29	-7739.
34	-15452.
39	-24357.
44	-36785.
49	-49640.
54	-67175.
58	-91690.
63	-121821.
66.7	-145615.
73	-108192.
78	-84137.
83	-63704.
88	-46372.
93	-32204.
97	-19503.
102	-8032.
107	558.
112	7503.
117	12717.
122	16944.
127	20007.
132	22076.
136	22900.
141	21691.
146	18120.
151	14417.
156	10361.
161	5161.
166	-1150.
170	-8135.
175	-4152.
180	-1794.
185	-444.
190	0.

FIGURE B-15

DYNAMIC BENDING MOMENTS
ROTATIONAL EDGEWISE DROP
(AFT END 18.0 INCHES)

Scale: 0 — 19000 — 38000 — 57000 — 76000

IS IN	DYM IN-LBS
0	0.
5	0.
10	0.
15	-4.
19	-34.
24	-130.
29	-2163.
34	-4347.
39	-6968.
44	-10900.
49	-15016.
54	-21279.
58	-30973.
63	-43664.
66.7	**-54134**
73	-24482.
78	-4853.
83	12143.
88	26715.
93	38620.
97	49214.
102	58596.
107	64951.
112	69446.
117	71846.
122	72938.
127	72397.
132	70347.
136	66198.
141	58476.
146	46199.
151	33648.
156	20256.
161	3999.
166	-15314.
170	**-36632.**
175	-19631.
180	-8877.
185	-2312.
190	0.

TABLE B-4

RESPONSE TO 25G, 25MS HALFSINE SHOCK SUMMARY TABLE

INPUT PARAMETERS

SUPPORT LOCATIONS(IS)	FWD	66.70
	AFT	170.00
LONGITUDINAL SHOCK FREQUENCY-HIGH TEMPERATURE		8.60 HZ
	LOW TEMPERATURE	10.40 HZ
IMPACT VELOCITY		12.00 FPS
LOCATION OF LONG FRICTION RESTRAINTS(IS)		66.70
		170.00
MAGNITUDES OF THE FRICTION FORCES		9000.00 LBS
		9000.00 LBS
NUMBER OF LONGITUDINAL BEARING RESTAINTS		1
LOCATION OF LONG BEARING RESTRAINTS(IS)		136.00
ECCENTRICITIES		7.75 INS

RESULTS

DISPLACEMENT			2.67 INS
DECELERATION			24.35 G
DYNAMIC SUPPORT REACTIONS	FWD		2039.55 LBS
	AFT		-674.47 LBS
DYNAMIC BENDING MOMENTS	FWD		-8030.66 IN-LBS
	AFT		-1816.03 IN-LBS
DYNAMIC BENDING MOMENTS AT LONGITUDINAL RESTRAINTS			
1ST BEARING RESTRAINT		82861.37	-35230.21 IN-LBS

REMARKS

IMPACT VELOCITY EQUIVALENT NOT ACTUAL (SEE TEXT P.11)

FIGURE B-16
ITEM DYNAMIC MOMENTS
END IMPACT ANALYSIS
IMPACT VELOCITY 12.00 FEET PER SECOND

IS IN	DYM IN-LBS
0	0.
5	0.
10	0.
15	-1.
19	-7.
24	-27.
29	-398.
34	-795.
39	-1258.
44	-1916.
49	-2598.
54	-3554.
58	-4930.
63	-6652.
68	-5620.
73	1964.
78	9294.
83	16373.
88	23229.
93	29850.
97	36359.
102	42769.
107	48941.
112	54971.
117	60847.
122	66630.
127	72300.
132	77868.
136	82861.
141	-29583.
146	-24656.
151	-19745.
156	-14883.
161	-10183.
166	-5652.
171	-1976.
175	-965.
180	-433.
185	-112.
190	-0.

Plot axis: 0, 21000, 42000, 63000, 84000

FIGURE B-17
ITEM AXIAL LOADS
END IMPACT ANALYSIS
IMPACT VELOCITY 12.00 FEET PER SECOND

IS IN	AXL LBS
0	0.
5	1.
10	2.
15	15.
19	61.
24	895.
29	1969.
34	2008.
39	3233.
44	3318.
49	3860.
54	5842.
58	7746.
63	9431.
66.7	10697.
73	3390.
78	4646.
83	5857.
88	6977.
93	7940.
97	8342.
102	9211.
107	10160.
112	10953.
117	11496.
122	12082.
127	12617.
132	13033.
136	14508.
141	140.
146	847.
151	906.
156	1515.
161	2349.
166	3464.
171	3236.
175	-3229.
180	-2092.
185	-1047.
190	-167.

TABLE B-5

RESPONSE TO 15G, 35MS TRAPEZOIDAL SHOCK SUMMARY TABLE

INPUT PARAMETERS

SUPPORT LOCATIONS(IS)	FWD	66.70
	AFT	170.00
VERTICAL SHOCK FREQ		9.10 HZ
DROP HEIGHT		20.10 INS
WEIGHT OF THE CONTAINER SHELL		600.00 LBS

RESULTS

PRIMARY-		
DISPLACEMENT		2.30 INS
DECELERATION		19.46 G
REBOUND-		
DISPLACEMENT		0.70 INS
DECELERATION		5.94 G
DYNAMIC SUPPORT REACTIONS	FWD	17443.70 LBS
	AFT	9121.72 LBS
DYNAMIC BENDING MOMENTS	FWD	-156282.26 IN-LBS
	AFT	-35341.19 IN-LBS

REMARKS

DROP HEIGHT EQUIVALENT NOT ACTUAL (SEE TEXT P.11)

FIGURE B-18
FLAT DROP ANALYSIS
PLOT OF DYNAMIC BENDING MOMENTS VERSUS ITEM STATIONS
DYNAMIC BENDING MOMENTS(DYM)= +

IS IN	DYM IN-LBS
0	0.
5	0.
10	0.
15	-19.
19	-145.
24	-524.
29	-7741.
34	-15477.
39	-24489.
44	-37282.
49	-50554.
54	-69171.
58	-95941.
63	-129459.
66.7	-156282.
73	-103656.
78	-69377.
83	-40005.
88	-14967.
93	5494.
97	23775.
102	40138.
107	51861.
112	60830.
117	66791.
122	70948.
127	72906.
132	72894.
136	70251.
141	63195.
146	50692.
151	37871.
156	24109.
161	7186.
166	-13021.
170	-35341.
175	-18777.
180	-8427.
185	-2177.
190	-0.

TABLE B6

RESPONSE TO 9G, 35MS TRAPEZOIDAL SHOCK SUMMARY TABLE

INPUT PARAMETERS

SUPPORT LOCATIONS(IS)	FWD	66.70
	AFT	170.00
TRANSVERSE SHOCK FREQUENCY-	HIGH TEMPERATURE	17.30 HZ
	LOW TEMPERATURE	17.30 HZ
IMPACT VELOCITY		4.97 FPS

RESULTS

AT LOW TEMPERATURE

DECELERATION		16.77 G
DYNAMIC SUPPORT REACTIONS	FWD	15036.26 LBS
	AFT	7862.81 LBS
DYN BENDING MOM AT SUPPORTS-	FWD	-134713.45 IN-LBS
	AFT	-30463.69 IN-LBS

AT HIGH TEMPERATURE

DISPLACEMENT	0.55 INS

REMARKS IMPACT VELOCITY EQUIVALENT NOT ACTUAL (SEE TEXT, P.11)

FIGURE B-19

DYNAMIC BENDING MOMENTS
SIDE IMPACT ANALYSIS
IMPACT VELOCITY 4.97 FEET PER SECOND

Plot scale (MOM, IN-LBS): 0, 34000, 68000, 102000, 136000

IS IN	MOM IN-LBS
0	0.
5	0.
10	0.
15	-16.
19	-125.
24	-452.
29	-6672.
34	-13341.
39	-21110.
44	-32137.
49	-43577.
54	-59625.
58	-82700.
63	-111592.
66.7	-134713.
73	-89350.
78	-59302.
83	-34484.
88	-12901.
93	4736.
97	20494.
102	34599.
107	44704.
112	52434.
117	57573.
122	61156.
127	62844.
132	62334.
136	60556.
141	54474.
146	43696.
151	32645.
156	20781.
161	6194.
166	-11224.
170	-30463.
175	-16186.
180	-7264.
185	-1876.
190	-0.

TABLE B-7

RESPONSE TO 6G, 35MS TRAPEZOIDAL SHOCK SUMMARY TABLE

INPUT PARAMETERS

SUPPORT LOCATIONS(IS)	FWD	66.70	
	AFT	170.00	
LONGITUDINAL SHOCK FREQUENCY-	HIGH TEMRERATURE	9.10	HZ
	LOW TEMPERATURE	9.10	HZ
IMPACT VELOCITY		4.39	FPS
LOCATION OF LONG FRICTION RESTRAINTS(IS)		66.70	
		170.00	
MAGNITUDES OF THE FRICTION FORCES		9000.00	LBS
		9000.00	LBS
NUMBER OF LONGITUDINAL BEARING RESTAINTS		1	
LOCATION OF LONG BEARING RESTRAINTS(IS)		136.00	
ECCENTRICITIES		7.75	INS

RESULTS

DISPLACEMENT		0.92	INS
DECELERATION		7.79	G
DYNAMIC SUPPORT REACTIONS	FWD	344.14	LBS
	AFT	1020.94	LBS
DYNAMIC BENDING MOMENTS	FWD	-8030.66	IN-LBS
	AFT	-1816.03	IN-LBS

DYNAMIC BENDING MOMENTS AT LONGITUDINAL RESTRAINTS

1ST BEARING RESTRAINT	-34630.27	22413.59	IN-LBS

REMARKS IMPACT VELOCITY EQUIVALENT NOT ACTUAL (SEE TEXT P.11)

HIGH TEMPERATURE= LOW TEMPERATURE= 70 DEG. F

AD-A051 422 NAVAL WEAPONS HANDLING CENTER COLTS NECK N J F/G 16/1
DYNAMIC ANALYSIS OF SHIPPING CONTAINER SUSPENSION SYSTEM FOR TH--ETC(U)
MAY 77 G JOHNSON
UNCLASSIFIED NWHC-7732 NL

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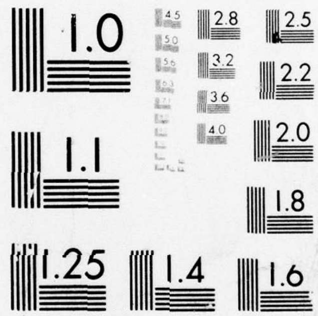

MICROCOPY RESOLUTION TEST CHART
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FIGURE B-20
ITEM DYNAMIC MOMENTS
END IMPACT ANALYSIS
IMPACT VELOCITY 4.39 FEET PER SECOND

DYM axis (IN-LBS): 0, 9000, 18000, 27000, 36000

IS IN	DYM IN-LBS
0	0.
5	0.
10	0.
15	-1.
19	-7.
24	-27.
29	-398.
34	-795.
39	-1258.
44	-1916.
49	-2598.
54	-3554.
58	-4930.
63	-6652.
68	-8174.
73	-8848.
78	-9777.
83	-10958.
88	-12361.
93	-14000.
97	-15751.
102	-17601.
107	-19688.
112	-21918.
117	-24302.
122	-26779.
127	-29368.
132	-32059.
136	-346300
141	19106.
146	15773.
151	12424.
156	9026.
161	5467.
166	1738.
171	-1348.
175	-965.
180	-433.
185	-112.
190	0.

FIGURE B-21

ITEM AXIAL LOADS
END IMPACT ANALYSIS
IMPACT VELOCITY 4.39 FEET PER SECOND

IS IN	AXL LBS
0	0.
5	0.
10	1.
15	5.
19	20.
24	286.
29	630.
34	643.
39	1035.
44	1062.
49	1236.
54	1870.
58	2480.
63	3019.
66.7	5575.
73	-5034.
78	-4632.
83	-4244.
88	-3886.
93	-3578.
97	-3449.
102	-3171.
107	-2867.
112	-2613.
117	-2439.
122	-2252.
127	-2080.
132	-1947.
136	5885.
141	6164.
146	6390.
151	6409.
156	6604.
161	6871.
166	7228.
171	6084.
175	-1033.
180	-670.
185	-335.
190	-53.